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A

TEXT-BOOK

ON

ANATOMY, PHYSIOLOGY, AND HYGIENE.

FOR THE USE OF

SCHOOLS AND FAMILIES.

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PREFACE.

HAVING been engaged for many years in lecturing upon the various branches of Natural History, and having experienced the difficulty that exists in attempting to teach Anatomy and Physiology without a text-book adapted to the wants of collegiate classes, I have ventured to publish my course of lectures on these subjects in the form herein presented, that the students of the Free Academy may have every opportunity of perfecting themselves in these branches as thoroughly as the limited time devoted to them will permit.

Although the chief object has been to prepare a text-book for academic students, the work is also designed for the use of schools and families; and students of medicine will find that it contains a few hints of value to them, especially in Lecture XXVII., which has been added for their benefit.

The division of Hygiene will be found to present many facts of interest to the general reader; and, in view of the measured but apparently inevitable approach of cholera to our shores, we have in the last lecture given a short summary of the means by which we may hope to avoid its attack.

Anatomy and Physiology have been subjects of study for many centuries, and there is but little that an author can say regarding them that is novel or original. I would therefore call attention to the results of the experiments on urea, and to the conclusions drawn from them, and acknowledge my indebtedness to the works of Carpenter, Cruveilhier, Marshall, Dunglison, Bowman, Draper, and many other men of science, whose labors and writings are quoted, and whose opinions have been adopted.

Finally, to the Board of Education of the City of New York I would express my sincere thanks for the liberal manner in which they have enlarged the ordinary collegiate course by ingrafting on it the study of modern sciences, and enabling the young men who graduate from the Free Academy to obtain a knowledge of the construction and workings of the human system, which is by all considered to be a necessary part of a liberal education.

FREE ACADEMY, NEW YORK, *Nov.* 30, 1865.

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ANATOMY, PHYSIOLOGY, AND HYGIENE.

FIRST DIVISION.

ANATOMY AND STATICAL PHYSIOLOGY.

LECTURE I.

INTRODUCTION.

Theories regarding the Nature of Life.—The Food introduced into the System is combustible.—The Substances voided from the Body are all burnt or oxidized.—The Methods to be employed in the Examination of the Structure and Function of Organisms endowed with Life.—Cells enter into the Composition of all Tissues and Creatures.

WHAT IS LIFE? The philosophers of past times tell us that it is an inborn, inherent power, by which plants and animals resist for a time the decay and final oxidation or destruction to which they must sooner or later submit.

The physiologist of the present day demonstrates, by experiments which we can not refute, that the oxidation of the materials introduced into the system as food is one of the essential conditions for the maintenance of life.

Unless we breathe air, or some gas containing oxygen, death is in a few moments the inevitable result. Without water, we may for a short time exist, tortured by an agonizing thirst. Without food, life may be prolonged for two or three weeks, or even a month; but starvation will have so weakened the powers of the sufferer that he is either reduced to a condition of hopeless delirium, or the hasty, careless introduction of food into the stomach will produce a shock from which the system can not recover.

If we submit the substances employed as food to chemical analysis, we find that they are, without exception, composed of carbon and hydrogen, to such an extent as to furnish a considerable amount of heat when burned in the air; they are there-

What was the old theory regarding life? What is the modern idea of life? What is the composition of food?

fore combustible. If we examine in a similar manner the materials ejected from the body, we find that they have been more or less perfectly oxidized in the system, and are incapable of being burned.

From such facts as these, we conclude that the essential condition for the proper maintenance of life in man and animals is a sufficient supply of air, water, and food. We may regard ourselves as machines, in which power is produced by the oxidation of a certain quantity of combustible material; and as in a steam-engine power is generated by the combustion in the furnaces of the boiler, so in man the oxidation of nerve and muscle are absolutely necessary for the production of thought and action.

The decay and death of the tissues are essential to the existence of the individual. The human machine wears away by use, and man can not live but by the destruction and reproduction of the cells of which the body is composed.

Life, therefore, is not a condition of stability, a power possessed by plants and animals of resisting the great physical laws of nature; it is produced by them, and is subject to their domination. The wonderful enigma of our existence has been beautifully expressed by one of the greatest of modern physiologists, who says: "An organism, no matter of what grade it may be, is only a temporary form, which myriads of particles passing through a determinate career give rise to. It is like the flame of a lamp, which presents for a long time the same aspect, being ceaselessly fed as it ceaselessly wastes away."

As we seek to explain the ordinary phenomena with which we come in contact by observation and experiment, so in physiology we should, as far as is expedient, endeavor to examine into the operations of the organs and glands of the body by a careful study of their structure and action. If we find that certain articles are conveyed to a manufactory, and in due course of time other materials of greater value are produced, we investigate the nature of the machinery and the materials used, and have no difficulty in understanding the processes employed. So with any organ or gland, if we carefully examine its structure, the materials conveyed to it and those which it produces, we sooner or later arrive at a rational explanation of its action and function.

Applying a similar system of investigation to living crea-

What is the nature of the substances voided from the system? What substances are required for the proper maintenance of life?

tures and the tissues composing them, we find, on submitting them to the test of the microscope, that they are constructed of cells, and fibres which originate in a cell, which is the simplest form of living organism, and invariably consists of certain parts, without regard to its function or the structure it may compose.

LECTURE II.

CELLS.

Parts composing a Cell.—Vegetable and Animal Cells.—All living Things originate in and are composed of Cells.—Reproduction of Cells.—Formation of Tissues from Cells.—Secreting and protecting Cells.—Cells enter into the Composition of Liquids.—Nutrition of Cells.—Definitions of Anatomy, Physiology, and Hygiene.

If the dust-like pollen from a flower is placed under the microscope, we find that it is composed of small spheroidal or elliptical bodies. In such organic atoms there resides a power which can fructify female flowers, and initiate all the wonderful phenomena which result in the production of a perfect plant.

This minute microscopic body is called a *cell*. It consists of an external membrane or cell wall, which incloses the cell contents. These may be either fluid or solid, depending upon the character of the cell. The defined separate mass contained in the interior is called the nucleus; in it the changes to which

Fig. 1.

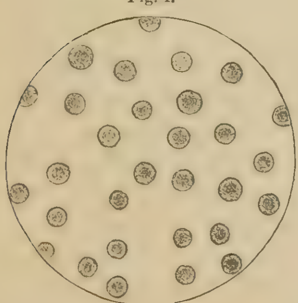
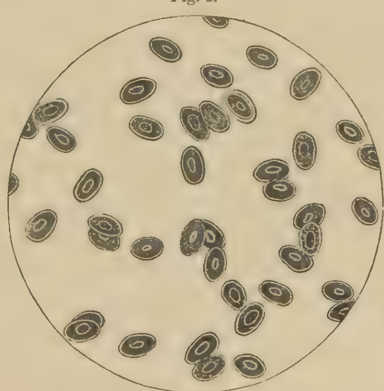


Fig. 2.



Cells showing Nuclei.

What is the simplest form of living organism? What is the appearance of the pollen of flowers under the microscope? What are the parts of a cell? What is a nucleus?

the cell is liable usually commence. Sometimes the nucleus itself contains a germinal spot, to which the name of nucleolus is given.

The simplest example of animal as well as vegetable life is also a cell. Of this we may satisfy ourselves by placing under the microscope some of the green slimy material called conferva, which grows in stagnant water. At first we only see the elongated cells which form the fibres of the plant; but as we examine their various-shaped nuclei, we are surprised from time to time by circular bodies which dash across the field of the instrument with great rapidity, and seem not only to possess the power of voluntary motion, but also the capability of directing their course into any desired path. These are monads, or cells endowed with voluntary motion; they therefore belong to the animal kingdom, for the possession of this power is the true distinguishing mark between a plant and an animal.

Examining the germ from which any given animal originates, we find that it also is a nucleated cell. Since, therefore, all living things, whether they belong to the animal or vegetable kingdom, originate in and are born from cells, we must regard these minute organisms with peculiar interest, and endeavor to familiarize ourselves with their various forms, and their methods of reproduction.

An excellent illustration of a simple cell is offered by an egg, in which the shell represents the cell wall, the white the cell content, the yolk the nucleus, and the germinal spot of the yolk the nucleolus.

In the eggs of some of the lower forms of animal life we can at our leisure watch the development, growth, and final production of the perfect creature almost as easily as we can trace similar operations in vegetable cells. The processes in both are the same, but since the vegetable cells offer fewer obstructions to the use of the microscope in the study of their reproduction, we shall deal chiefly with them.

Fig. 3.

Reproduction of Cells by Section.

Cells are multiplied or reproduced either by section or by granulation. In the first the cell wall gradually doubles in toward the nucleus, so as

What is conferva? What is its composition? What are monads? What is the essential difference between a plant and an animal? What is the origin of a plant or an animal? Illustrate the parts of a cell by those of an egg? How are cells reproduced?

Fig. 4.

Reproduction of Cells by Granulation.

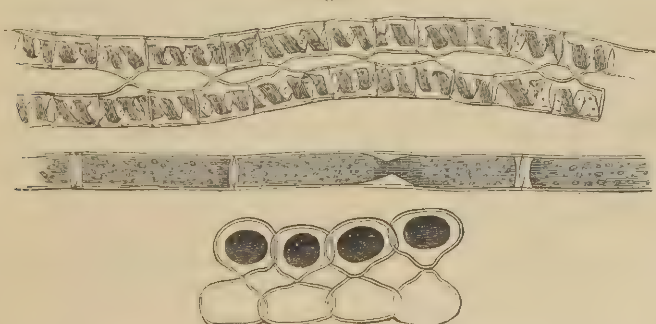
to give the cell a dumb-bell form, which becomes by degrees more and more complete, until it is finally divided through the nucleus and two perfect cells produced. In reproduction by granulation the movement commences in the nucleus. It breaks up into exceedingly minute grains, which form nucleoli, that gradually enlarge until they fill the nucleus, which soon disappears, and the cell seems to be filled with nuclei. The wall then bursts, and the nuclei, being set free, become new, perfect cells.

Fig. 5

Mural Tissue.

In order to form tissues, cells are sometimes arranged as in *Fig.* 5, presenting an appearance similar to that of a wall built of cut stone. Such are called mural tissues. Sometimes cells are elongated and placed end to end, as in the fibres of the yeast plant and conferva. In other instances the cells become greatly elonga-

Fig. 6.



Varieties of Conferva showing the shape of the Cells and Nuclei.

Describe reproduction by section and granulation. How do cells form tissues?

ted, as in in voluntary muscle and fibrous tissues. If the cells retain their spherical figure the organs formed produce secretions, while in the skin and all structures intended merely for protection, they dry up and become scale-like.

Fig. 7.

Yellow fibrous Tissue.

Not only are tissues composed of cells, but all animal fluids, as for example blood, contain one or more special forms of cells by which we can often detect their presence. The description of these, as well as of the cells of special tissues, as muscle and nerve, must be reserved until we reach the discussion of such fluids and organs.

In order that a simple organism like a cell shall exist and grow, it must be supplied with proper nutriment. The tissues of men and animals, being formed of cells, must therefore be furnished with the materials required for their growth and development.

To satisfy the stern necessity that Nature has thus impressed on all animals, that they should seek their food, she has mercifully provided them with bodies constructed in such a manner as to be capable of motion, and possess the power of converting various articles of food into a nutritious fluid, on which tissues may feed.

The study of the body is divided into two distinct branches, Anatomy and Physiology. The first deals with its structure; the second treats of the functions of the organs of which it is composed. To these we may add a third, Hygiene, which examines into the conditions most favorable for the maintenance of perfect health.

Physiology is, by Professor J. W. Draper, divided into Static and Dynamic Physiology. The first relates to man as an individual, and discusses the functions of the different organs of the body. The second treats of man in his social state, and deals with nations or masses of men, examining into their rise, progress, and influence on each other. The advantages attending this division are so self-evident that we shall adopt it without discussion.

What is the difference between a secreting and a protecting cell? Into what branches is the study of the body divided? What is Anatomy? What is Physiology? What is Hygiene? What are the divisions of Physiology?

In describing the various organs of the body, we shall first explain the anatomical structure of each, and then pass to the consideration of its function, so that the structure and function may be connected with each other in the mind of the student, and more readily recollected.

LECTURE III.

ANATOMY OF THE HUMAN BODY.

The Tissues and Fluids composing the Body.—Divisions of the Body.—Cavities of the Head, their Contents.—Cavities of the Trunk and their Contents.—Subdivisions of the Extremities.—The Skeleton, its Uses.—Composition of Bone, and variations in the Proportions of its Ingredients.—Diseases of Bone.—Importance of Bones in certain Manufactures.—Microscopic Appearance of Bone.—Membranes of Bone.—Division and Classification of Bones.

The body is composed of solid tissues or organs, and fluids. They are,

1st. Bone, which supports the other tissues and organs, and gives a fixed figure and form.

2d. Ligament and cartilage connect the bones and form a skeleton, possessed of joints and capable of motion.

3d. Muscle, endowed with the property of contractility, gives motion to the body.

4th. Organs of nutrition, divided into digestive, absorptive, and circulatory.

5th. Organs of secretion and excretion, as the lungs and kidneys.

6th. Nervous tissue regulates the action of the muscles and all the organs of the body.

7th. Special senses—vision, hearing, smell, taste, and touch—by which the system is brought in communication with external objects.

8th. Areolar or connective tissue.

9th. The skin and its appendages.

10th. The organs of reproduction.

The fluids of the system are,

1st. *Blood*, which may be arterial or venous. The first is bright red, owing to its containing oxygen; while venous blood is dark blue, and contains carbonic acid.

What are the tissues of the body? What are the uses of bone? of ligament and cartilage? of muscle? What are the organs of nutrition? Give examples of the organs of excretion. What is the function of nervous tissue? Name the special senses. What are the fluids of the body? What is the difference between arterial and venous blood?

2d. *Chyme* and *chyle.* The first is a tawny yellow color, and formed during digestion in the stomach. The second is milky, and is found in the small intestines and lacteals.

3d. *Lymph*, a colorless fluid, contained in minute vessels called lymphatics. It represents the excess of nutriment conveyed to various parts of the body.

4th. *Bile*, a yellow or greenish fluid secreted by the liver. It sometimes becomes condensed, and forms hard masses called gall-stones, which cause excruciating pain as they pass into the intestine.

5th. *Digestive juices*, consisting of saliva, gastric, pancreatic, and intestinal juices.

6th. *Excretions* and *secretions*, such as urine, sweat, milk.

For the sake of convenience, the body is described under six divisions—head, trunk, and four extremities.

The head contains the following cavities: 1st. The cranial, which accommodates the brain; 2d. The buccal, in which the tongue and teeth are placed; 3d and 4th. The orbital, containing the eyes; and, 5th. The nasal, inclosing the organ of smell.

The trunk is divided into three cavities: 1st. The thoracic, which has yielding bony walls, and contains the heart, lungs, great blood-vessels, and air-tubes; 2d. The abdominal, surrounded by soft, yielding muscular walls, and separated from the thoracic by a muscle called the diaphragm.

The abdominal cavity contains the liver, which lies immediately under the diaphragm, and chiefly on the right side; the stomach, under the liver and on the left side; the spleen, on the left of the stomach; the kidneys, in the back of the cavity; the intestines, in front and on the sides; the pancreas, beneath and behind the stomach.

The pelvic cavity, inclosed by unyielding bony walls, contains the bladder in the male, and the bladder and uterus in the female.

The extremities are divided into the upper and lower. The subdivisions of the upper extremities are the shoulder, arm, forearm, and hand. Those of the lower extremity are the hip, thigh, leg, and foot.

With these preliminary remarks regarding the general char-

What is the difference between chyme and chyle, and where are they found? What is lymph, and in what vessels is it found? What is bile? How are gall-stones formed? What are the digestive juices? What are the divisions of the body? What cavities are found in the head? What do they contain? Name the cavities in the trunk. What are the contents of the thoracic—of the abdominal—of the pelvic cavity? What are the subdivisions of the upper extremity? of the lower extremity?

acters of the tissues and fluids of the body, we now pass to the study of

THE SKELETON.

All animals are provided with a more or less perfect skeleton, the object of which is to furnish a support for the various soft tissues and organs, or to protect them from injury and violence. In the lower orders it is often placed on the outside of the body, and is the only protection the creature has against the attacks of its numerous enemies. An excellent illustration of this arrangement is afforded by the oyster, which is furnished with a hard shell or exterior skeleton, the chief use of which is to protect the soft tissues from injury.

Passing a little higher in the scale, we find that the lobster and such creatures are endowed with a far greater freedom of motion than the oyster; consequently, though their skeletons are on the outside of the body, they are built on a different plan; the various parts are lighter, and arranged so as to furnish a system of jointed levers and supports, by which the creature can at its will transport itself from one place to another, and avoid its enemies, or obtain the food necessary for its proper nourishment.

Though a certain degree of facility of motion can be reached by means of an exterior skeleton, yet it is almost incompatible with such perfect freedom as is required in the higher animals; consequently we find that in fishes, reptiles, birds, and beasts, the skeleton is in the interior of the body. It is every where covered by soft tissues, and is arranged so as to furnish levers for the organs of locomotion, or form cavities in which the more delicate organs, as the brain, heart, lungs, and digestive apparatus, may be properly protected from injury.

In man and animals, the separate pieces of which the skeleton is composed are called *bones*. These differ in their form so as to fulfill the purposes for which they are intended, but in chemical composition they show but slight variation.

Analysis of Bone.

Cartilage or gluten	32.17	Animal or organic	33.30
Blood-vessels	1.13		
Phosphate of lime	51.04	Mineral or inorganic	66.70
Carbonate of lime	11.30		
Fluoride of calcium	2.00		
Phosphate of magnesia	1.16		
Soda salts	1.20		
	100.00		100.00

What is the object of the skeleton? Is it always placed in the interior of the body? What are its uses in the higher animals? What are bones? What is the chemical composition of bone?

Examining the above analysis by Berzelius, we find that we may regard bone as being composed of animal and mineral substances in the proportion of one third of the former to about two thirds of the latter. This, although true in regard to bones of adults, is not the case in children and old people. In the former the proportion of animal material is far greater than one third, and consequently in infancy and early childhood the bones of the lower extremities are apt to bend if they are used too soon, since they are not sufficiently consolidated to support the weight of the body. The age at which they may with safety be used depends to a great extent on the diet and digestive powers of the child. If the food is not nutritious, or the constitution of the infant is poor, the proportion of animal material in the bones will be too great, and they will be flexible and bend, producing the deformity called rickets or bandy-legs, in which not only the bones of the legs, but also the ribs and pelvic bones, may be deformed to such an extent as to interfere seriously with the proper performance of the functions of the body.

In the osseous tissues of old people, on the contrary, the proportion of mineral matter is in excess; consequently their bones are very brittle, and break readily, often being fractured by such slight violence as making a false step while walking. Not only does age affect the composition of bone, but some bones always contain a greater proportion of mineral substance than others. For example, that in which the organ of hearing is situated possesses such a large proportion of inorganic substance as to have received the name of the *petrous*, or stone-like bone. With these exceptions, we may regard bone as having a uniform composition, represented by the analysis of Berzelius.

The presence of animal substances in bones may be readily demonstrated by burning them in a vessel from which the air is excluded. Treated in this manner, they turn black; the carbon of the animal substance remaining, while the hydrogen and oxygen are driven off. To the black residue obtained the name of animal or bone charcoal is given; it is of great value in certain manufactures, owing to the property it possesses of bleaching various organic colors. It is extensively used in refining sugar; the crude dark brown sugar being dissolved in

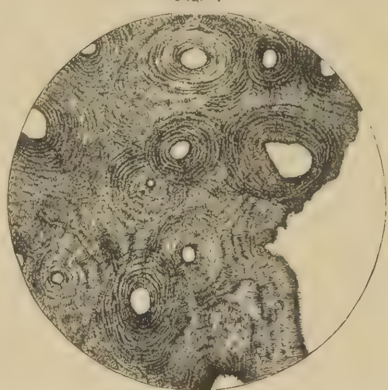
What are the proportions of animal and mineral substances in the bones of adults? What are the proportions in children? What is meant by rickets? What is the composition of bone in old persons? What bone contains the greatest amount of mineral substance? What is animal charcoal? How is it prepared? What are its uses?

water to form a sirup, which is passed through a column of coarsely-powdered bone charcoal, twelve or fifteen feet in length, and escapes below as a colorless fluid, which is evaporated and crystallized in masses, and returned to the market in the form of crushed and white sugar.

If the bones are burnt in a current of air, they finally become perfectly white; the mineral material, consisting chiefly of phosphate of lime, alone remaining. The bone-earth produced in this manner is in the form of powder used to make cupels for refining gold and silver; it is also employed as a fertilizer.

A very pretty method for separating the mineral from the animal materials is to place a bone in dilute hydrochloric acid, composed of one part of acid to ten or fifteen of water. In the course of a few days the acid dissolves all the mineral substance, leaving the animal material, which preserves the original figure of the bone, but is so flexible that it may be readily tied in a knot. The composition and growth of bones may be satisfactorily studied by the examination of their sections under the microscope. With a suitable power the appearance in Fig. 8 is obtained. The large openings are called the haversian canals, through which the larger blood-vessels pass to nourish the bone.

Fig. 8.



Section of Bone magnified 50 Diameters, showing Haversian Canals.

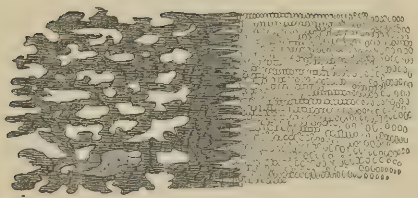
Fig. 9.

Section of Bone magnified 250 Diameters, showing Lacunæ and Canaliculi.

In Fig. 9 the fine lines are called canaliculi. They traverse the tissue in every direction, and convey the fluid portions of the blood to the lacunæ or bone cells which are scattered throughout the fabric, and

How is the refining of sugar conducted? For what purpose is bone-ash employed? Which ingredient of bone is soluble in acid? What is the appearance of bone under the microscope? What are the haversian canals? What are the lacunæ?

Fig. 10.



Cartilage ossifying, magnified 10 Diameters.

are represented in *Fig.* 9 by the black masses.

The development of bone first begins by the formation of a mass of cartilage which takes on the figure of the bone. In this a variable number of spots of true bone gradually appear which are centres of ossification. Around these the mineral matter is deposited until it extends throughout the mass, and it becomes perfectly consolidated, and possesses the rigidity necessary to adapt it to the purpose for which it is intended.

All bones are covered exteriorly by a membrane, in which the blood-vessels subdivide and form minute arteries, which enter the haversian canals to nourish the osseous tissue. To it the name of periosteum is given; and so necessary is this membrane to the well-being of the osseous tissue, that any injury to it results sooner or later in the death of the bone.

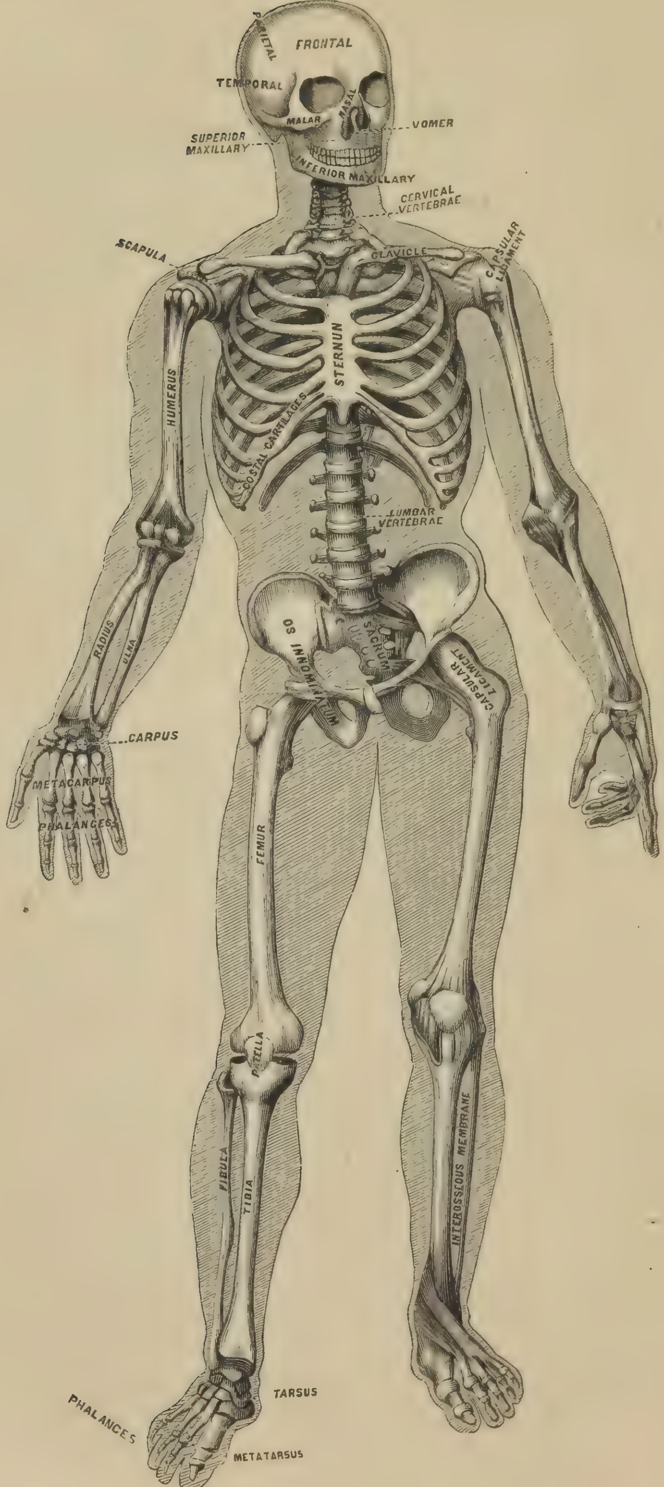
For convenience of description, bones are divided into three classes, long, flat, and irregular. The first are found in the extremities. They consist of a shaft composed of hard, dense tissue, usually hollow, and filled with marrow or fat. The cavity is cylindrical in shape, and lined with a membrane similar to the periosteum. It is called the endosteum; its duties are the same as those of the external membrane. The ends of the long bones are smooth, and enlarged to furnish surfaces suitable for the formation of firm joints. The canal of the shaft does not extend to the ends of the bone, but disappears in a species of cellular structure, which is better adapted to the conditions which are to be fulfilled by the extremities.

The flat and irregular bones usually inclose cavities, and are found in the skull, pelvis, and other regions. They are composed of two layers of hard, dense tissue, the intermediate space being occupied by spongy tissue, thus combining strength with lightness, as is also the case with the ends of long bones.

Bone, like the other tissues of the body, is subject to a number of diseases, such as cancer and inflammation, but the special trouble is the liability to fracture. When a bone is broken, if the fractured extremities are kept properly in juxtaposi-

How does the development of bone commence? What is the periosteum? What are the three classes of bones? Describe a long bone. What is the endosteum? How far does the canal of a long bone extend? What is the difference in structure between the shaft and extremities of a long bone? How are flat bones constructed?

Fig. 11.


PARIETAL
FRONTAL
TEMPORAL
NASAL
MALAR
VOMER
SUPERIOR MAXILLARY
INFERIOR MAXILLARY
CERVICAL VERTEBRAE
SCAPULA
CLAVICLE
CAPSULAR LIGAMENT
STERNUN
HUMERUS
COSTAL CARTILAGES
LUMBAR VERTEBRAE
OS INNOMINATUM
SACRUM
CAPSULAR LIGAMENT
RADIUS
ULNA
CARPUS
METACARPUS
PHALANGES
FEMUR
PATELLA
FIBULA
TIBIA
INTEROSSIOUS MEMBRANE
TARSUS
PHALANGES
METATARSUS

tion, they unite in a few days by the formation of cartilage, in which the mineral matter is gradually deposited, until, after the lapse of a few weeks, the juncture becomes more solid and dense than any other part.

In the Hunterian Museum there are many singular examples of diseased skulls, some being an inch thick, and others possessing osseous growths from various parts. In one which belonged to a prize-fighter, there are osseous projections from the rim of the orbits about three inches in length, which were produced by injuries received in various encounters.

LECTURE IV.

BONES COMPOSING THE SKELETON.

Number of Bones in the Body.—Bones of the Trunk.—Pelvic Bones.

The number of bones in the body varies at different ages, but in the adult there are 238. They may be conveniently studied under the following divisions:

Skull	Cranial	8
	Face	14
Trunk	Neck, thorax, and abdomen	50
	Pelvis	4
Upper extremities	Right, Left	64
Lower extremities	Right, Left	60
Internal ear		6
Teeth		32
		238

The bones of the skull are divided into those of the cranium, which inclose the cavity in which the brain is placed, and those of the face. The latter are very irregular, while the former are true flat bones.

The *cranial bones* are the frontal, occipital, sphenoid, ethmoid, two temporal, and two parietal.

The *frontal* forms the forehead and the roof of the orbital cavities, in which the eyes are placed.

The *occipital* (*Fig.* 12) forms the back of the head and part of the base of the skull. The large opening is the foramen magnum, through which the spinal cord passes.

The *sphenoid* (*Fig.* 13) bears some resemblance to a bat, be-

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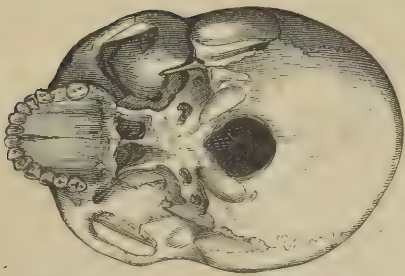
How is the fracture of bones repaired? How many bones are there in the body? How many in each division? Name the cranial bones. Describe the frontal, occipital, sphenoid bones.

Fig. 12.



Base of the Skull, showing the Occipital Bone and Foramen Magnum.

Fig. 13.

The Sphenoid.

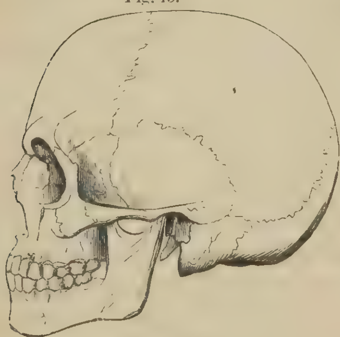
ing very irregular in form. It articulates with nearly all the bones of the skull, and forms the keystone to the arches of the cranium.

Fig. 14.

The Ethmoid Bone.

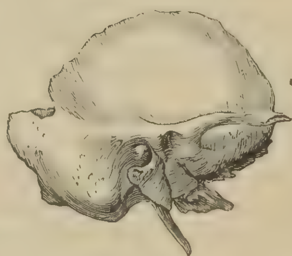
The *ethmoid* (*Fig.* 14) lies between the cranium and the face. It is composed of a number of very thin plates of bone, rolled into a mass of scroll-work, and covered by mucous membrane, in which the filaments of the olfactory nerve terminate to form the organ of smell.

Fig. 15.



Lateral view of Skull.

Fig. 16.



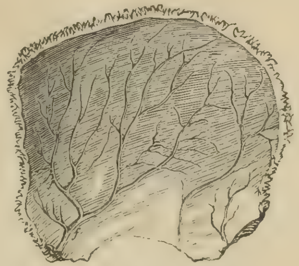
Temporal Bone.

The *temporal bones* aid in forming the base and sides of the skull. They are described as being composed of three parts: the mastoid, thick and cellular; the squamous, very thin and brittle; and the petrous, dense, hard, pyramidal in shape, and hollowed out in the interior into irregular cavities, which contain the small auditory bones. The sense of hearing is lodged in this part, the waves of sound reaching the interior cavities through an opening on the outside, called the meatus audito-

Describe the ethmoid and temporal bones.

rius externus, while the auditory nerve gains access to the same cavities through an opening near the apex of the petrous part called the meatus internus. The projecting arm of bone is called the zygoma, and the smooth glenoid cavity at its origin articulates with the lower jaw.

Fig. 17.

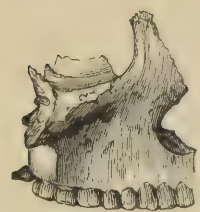


Parietal Bone, inner Surface.

The *parietal bones* are quadrilateral in shape, and form the sides and roof of the skull. The inner surface is grooved by arteries (*Fig.* 17), the rupture of which is one of the serious consequences of fracture of the skull.

The bones of the face are three maxillary, two nasal, two palate, two malar, two lachrymal, two turbinated, and one vomer.

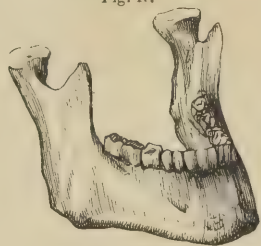
Fig. 18.



Superior Maxillary, outer Surface.

Superior Maxillary, inner Surface.

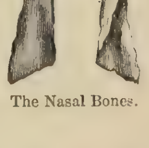
Fig. 19.



Inferior Maxillary.

There are two bones in the upper, and one in the lower jaw. The upper maxillaries form the floor of the orbital cavities, and present a number of projections, the most important of which are the alveolar process, in which the teeth are fixed; the palatal, which forms part of the hard palate; and the nasal, which forms the side of the nasal cavity. The body of the superior maxillary presents a large cavity called the antrum or cave, the object of which is to give resonance to the voice. The lower maxillary bone consists of a horizontal and ascending portion; the ends are smooth, to articulate with the temporal bone, while the teeth are fixed into the alveolar process of the horizontal portion.

Fig. 20.



The Nasal Bones.

The *nasal bones* form the upper hard part of the nose.

What is the zygoma? What is the name of the articular cavity? What are the three divisions of the temporal bone? What is the shape and position of the parietal bones? What are the bones of the face? Describe the upper maxillary bones. What is the antrum? Describe the lower maxillary bone. Where are the nasal bones?

The *palate bones* are shaped like the letter L. They assist in forming the hard palate.

The *malars* form the outer part of the orbital cavities, and the upper hard part of the cheeks.

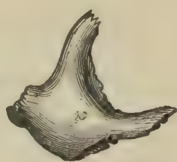
The *lachrymals* are small and very thin. They form a portion of the inner side of the orbits, and are in contact with the nasal processes of the upper maxillary.

The *turbinated bones* are in the nasal cavity, and attached to the ethmoid, in order to increase the surface on which the olfactory nerve is spread.

Fig. 21.

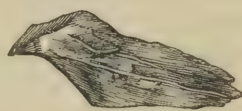
The Palate Bones.

Fig. 22.



The Malar Bone.

Fig. 23.



The Vomer.

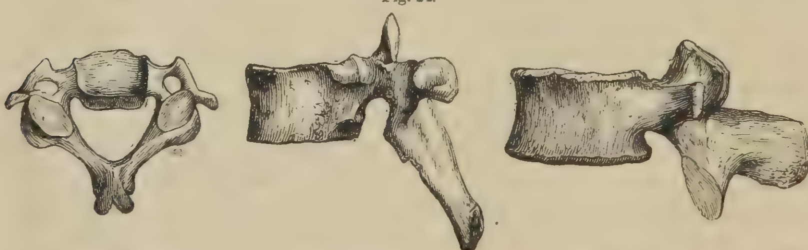
The *vomer* is shaped like a plow-share, and divides the nasal cavity into two equal lateral portions.

The bones of the trunk are the os hyoides, twenty-four vertebræ, twenty-four ribs, the sternum, two ossa innominata, the sacrum, and the coccyx.

The *os hyoides* is situated in the throat, at the base of the tongue.

The *vertebræ* are divided into three classes, seven cervical, twelve dorsal, and five lumbar. The cervical are the smallest,

Fig. 24.



Cervical Vertebra. Dorsal Vertebra. Lumbar Vertebra.

and are in the neck; the lumbar are the largest, and form the

Describe the palate bones. Where are the malar bones? Describe the lachrymal bones; the turbinated bones; the vomer. Name the bones of the trunk. Where is the os hyoides? What are the divisions of the vertebræ, and how many in each? In what part of the vertebral column are the largest bones found?

small of the back; the dorsal aid in forming the back of the chest, and they all possess facets on the sides, by which they articulate with the ribs.

Each vertebra consists of a body, and incloses an opening through which the spinal cord passes. The ring of bone of each vertebra that forms this opening terminates posteriorly in a sharp projection called the spinous process. The vertebræ are arranged one over another, and joined by ligaments and an intervening disc of elastic cartilage, so as to form a column, marked in the back by the row of rough projecting spinous processes. Between the vertebræ there are openings through which the spinal nerves pass.

Fig. 25.

The Vertebral Column.

Considered as a unit, the vertebral column forms a series of curves: one in the neck, the convexity of which looks forward; one in the chest, the convexity looking backward; one in the abdomen, with the convexity forward; and one in the pelvis, formed by the sacrum and coccyx, with the convexity backward.

These curves, and numerous vertebræ with their connecting cartilages, give to the column great elasticity, which protects the brain from injury by the sudden jars it would otherwise be subjected to in jumping and such violent movements. The lower part of the column is supported by the bones of the pelvis and legs, and in its turn gives support to the organs of the trunk, upper extremities, and head.

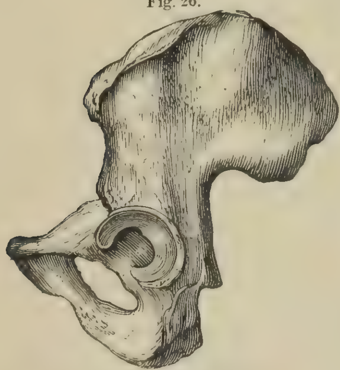
The *ribs* are about half an inch in width, and curved upon themselves so as to form an arc of a circle. One of the extremities is round and smooth, to articulate with one or two vertebræ; the other is rough, and gives attachment to a cartilage, by means of which the ribs are connected to the sternum. The under edge of each rib is marked by a groove, in which the arteries of the chest lie, and are protected from violence so perfectly that they are not readily reached in any ordinary wound

Describe a vertebra. How are the vertebræ connected? Describe the curves of the vertebral column. How is the lower part of the vertebral column supported? Describe the ribs. How do their extremities differ? How are the arteries of the chest protected?

by a knife. The seven upper ribs on each side are called true, and the five lower false ribs.

The *sternum* or breast-bone is flat, and connected with the ribs by costal cartilages; it articulates above with the clavicles.

Fig. 26.



The Os Innominatum.

The *ossa innominata*, so called from their want of resemblance to any other known natural object, are composed in infancy of three parts, which become consolidated into one bone in adults. They are called the ilium, ischium, and pubes. The first is the flaring portion, which forms the hip bone; the second is the lowest part, and terminates below in a rough mass called the tuberosity, which bears the weight of the body when in the sitting position; the third is the anterior portion.

The pubic bones unite in front to form an arch called the pubic arch, which is much more obtuse in the female than in the male. The three divisions of the innominatum meet in a smooth circular depression called the acetabulum, which accommodates the head of the femur to form the hip joint.

Fig. 27.

The Sacrum.

The *sacrum* is triangular in shape, and articulates laterally with the ossa innominata—above with the last lumbar vertebra, and below with the coccyx. It forms the posterior wall of the pelvic cavity, and is perforated on its anterior and posterior surfaces with a number of foramina or openings, through which the terminal divisions of the spinal cord pass.

The *coccyx* is a small triangular bone attached to the tip of the sacrum; it is the termination of the vertebral column.

The ossa innominata, sacrum, and coccyx form the pelvis, the shape of which varies with the sex. In the male it is cup-shaped, while in the female the iliac bones flare out so as to give it more the form of a saucer, and the cavity is wider in all its dimensions, and not so deep as in the male.

How many true and false ribs? Describe the sternum. Describe the ossa innominata. What are the divisions of the os innominatum? What is the tuberosity? What is the acetabulum? Describe the sacrum. Describe the coccyx. What is the pelvis?

LECTURE V.

THE SKELETON—*Continued.*

Bones of the Upper Extremity.—Bones of the Lower Extremity.—Varieties of Joints.—Tissues which enter into the Composition of Joints.—Joints and Bones form Levers.—Diseases and Wounds of Joints.

THE bones of the upper extremities are the scapula, clavicle, humerus, radius, ulna, eight carpal, five metacarpal, and fourteen phalanges.

Fig. 28.

The Scapula.

The *scapula*, or shoulder-blade, is held in position by muscles which are attached to the vertebræ and ribs so that it is movable. It is triangular in shape, the upper and outer angle furnishing an articular surface called the glenoid cavity, which receives the head of the arm bone to form the shoulder-joint.

Fig. 29.

The Clavicle.

The *clavicle* is shaped like the letter *f*. It is commonly known as the collar bone: its duty is to keep the shoulder-joint outward and backward. It is the first bone in the body that is perfectly ossified.

Fig. 30.

The Humerus.

The *humerus*, or bone of the arm, is a long bone, as are all the rest of the bones of the upper extremity except the carpal. The upper part is called the head; it articulates with the glenoid cavity of the scapula. On the outer side of the head there is a rough mass called the tuberosity, to which some of the muscles that move the arm are attached. The lower end of the bone is grooved, forming a hinge-like joint with the bones of the fore-arm.

The *radius* and *ulna* are the bones of the fore-arm. The ulna forms the elbow-joint, while the

What are the bones of the upper extremity? Describe the scapula; the clavicle; the humerus. With what cavity does the humerus articulate? What are the bones of the fore-arm? Which joint does the ulna chiefly form?

radius forms the wrist. They are placed side by side, and arranged so that the radius can move to a certain extent around the ulna, and give to the hand the movement of rotation it possesses.

The bones of the wrist, or *carpal bones*, are eight in number, and placed in two rows, the first containing the scaphoid, semilunar, cuneiform, and pisiform; the second the trapezium, trapezoides, magnum, and unciform.

The *metacarpal bones* are five in number, one for each finger; they articulate with the second row of carpal bones, and form the palm of the hand.

There are fourteen *phalanges*, three for each finger and two for the thumb.

The lower extremity is composed of the femur, patella, tibia, fibula, seven tarsal five metatarsal bones, and fourteen phalanges. They all belong to the order of long bones.

Fig. 31.

The Femur.

The *femur*, or thigh bone, has the head set on the shaft by means of a neck, which forms an angle that varies with the age of the individual. In old age the angle is nearly ninety degrees, and consequently the neck of the femur supports the weight of the body in the most disadvantageous manner, and is very liable to undergo fracture. The upper part of the bone is furnished with a strong, rough tuberosity for the attachment of muscles. The lower end is expanded so as to form two condyles, separated by a deep groove; it articulates with the tibia to form the knee-joint.

The *tibia* and *fibula* form the leg. They are closely bound together, and are not movable like the bones of the fore-arm.

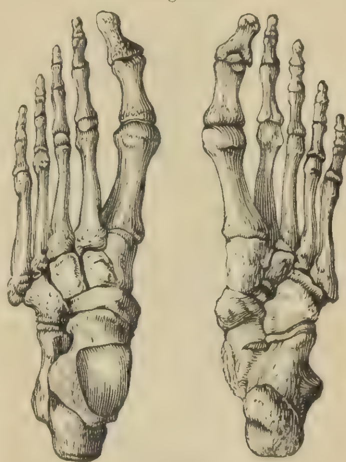
Which does the radius form? How many bones are there in the carpus? Name them. How many metacarpal bones are there? How many phalanges are there? Name the bones of the lower extremity. Describe the femur. How does the angle of the shaft and neck vary with age? What are the bones of the leg? What are their relations to the knee and ankle joints?

They terminate below in processes called malleoli, which give great firmness to the ankle-joint.

The *patella* lies in front of and protects the knee-joint. It is inclosed in the tendon of the muscles of the thigh, and enables them to act to greater advantage.

The *tarsal bones* are arranged in two rows. The first consists of the astragalus, which articulates with the bones of the leg to form the ankle, and the os calcis, which forms the heel. The second row is composed of the cuboid, scaphoid, and three cuneiform bones.

Fig. 32.



The Foot.

The *metatarsus* consists of five bones, one for each toe. They form the sole of the foot.

There are fourteen *phalanges*, three for each toe, except the large toe, which has two.

The bones of the internal ear will be described in connection with the sense of hearing.

The teeth belong properly to the function of digestion, and will be studied in connection with it.

THE JOINTS.

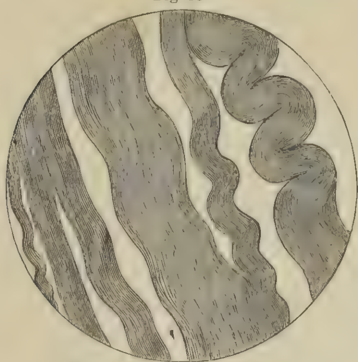
Bones are united together so as to form either immovable or movable joints. The best example of the first class is furnished by the skull. In it the various bones are dovetailed into each other along their edges, to form perfectly unyielding joints called *sutures*, which may be broken, and the bones obtained separately, by filling the cranial cavity with well-dried peas, and adding water, when the peas swell and force the bones apart. The joints of the second class vary greatly in the degree of mobility they possess, from the sliding motion of the bones of the carpus on each other, to the hinge-like motion of the knee or elbow, or the almost universal mobility of the ball and socket joints of the hip and shoulder.

The tissues which enter into the formation of a movable joint are, 1st. The smooth articular ends of the bones; 2d. A

Describe the patella. Name the tarsal bones. How many metatarsal bones and phalanges are there? Describe the two varieties of joints, and give examples of each. What are sutures? What tissues enter into the formation of a joint?

covering of very dense polished cartilage, which gives a slight degree of elasticity, and aids in reducing the friction; 3d. Ligaments, which bind the bones together; 4th. The synovial membrane or sac, which contains the fluid, and lies between the cartilages of the joint, its object being to reduce the friction; 5th. Muscles, which move the bones; and, 6th. Nerves, which govern and regulate the actions of the muscles.

Fig. 33.

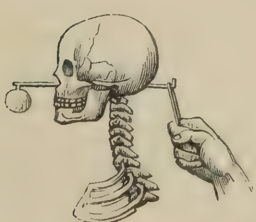


White Fibrous Tissue, magnified 300 Diameters.

The osseous tissue has already been described. Cartilage consists of cells and fibrous tissue. Ligament is composed of white fibrous tissue, in which the cells have become elongated into mere lines; it is admirably adapted to the purpose for which it is employed. The synovial sac is also composed of fibrous tissue, and lined with serous membrane. These are the essential tissues of the joint; the muscles and nerves are auxiliary. We may therefore pass at once to the study of the joints, and then take up the examination of the muscular and nervous tissues.

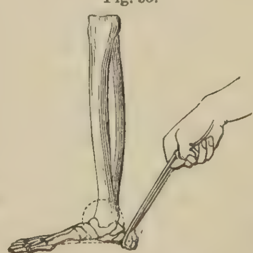
All the long bones, and some of the bones of the other classes, are used in the construction of movable joints, serving either as levers to move the body, or to carry on some process necessary to the well-being of the system, as, for example, mastication. There are three classes of levers, all of which are represented in the body. In the first class, the fulcrum is between the power and the resistance; in the second, the resistance is

Fig. 34.



Lever of 1st Class.

Fig. 35.



Lever of 2d Class.

Fig. 36.

Lever of 3d Class.

What is cartilage? Describe cartilage and ligament. Describe the synovial sac and fluid. What are the varieties of levers?

in the centre; and in the third the power is in the middle. In the systems of levers in the body, the fulcrum is the joint and the power the muscle. In throwing the head backward we have an example of a lever of the first class; in raising the body on tip-toe we have an example of the second; and in flexing the fore-arm on the arm we have an example of the third.

Joints, like the other parts of the body, are liable to inflammation. When the ligaments are involved, it is called rheumatism; this sometimes passes into a chronic state, and is exceedingly painful. When the synovial membrane and cartilages are involved, it is called white swelling, which is very apt to terminate in a union of the bones and entire loss of the use of the joint. Sometimes small hard cartilages are formed in the knee-joint, which slip between the ends of the bones in walking, and produce the most excruciating pain. Wounds of the large joints, though they may appear to be insignificant, are very dangerous, and often cause death if the joint is opened to the access of air.

LECTURE VI.

THE MUSCULAR SYSTEM.

The Muscular Tissue.—Microscopic Characters of voluntary and involuntary Muscle Cells.—Tendons and their Position.—Divisions of Muscles.—Muscles of the Head and Neck.—Of the Upper Extremities.—Of the Trunk.—Of the Lower Extremities.

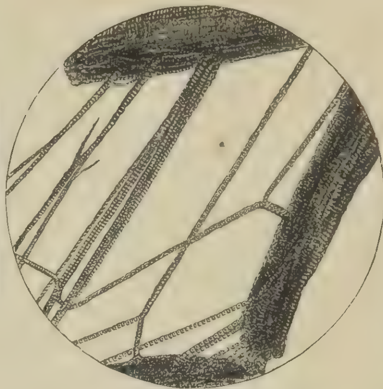
THE muscular tissue forms the bulk of the body; it is very freely supplied with blood-vessels, and is of a deep red color in the majority of animals, forming the lean meat or flesh—an excellent example being the beef prepared for sale in the markets. There are, however, exceptions to the general law, as in the breasts of fowls, where it is white; this is supposed to be in part due to the fact that the pectoral muscles in such creatures are not used to any great extent, and they therefore undergo a fatty degeneration, and lose their color. The chemical elements entering into the composition of this tissue are carbon, hydrogen, oxygen, nitrogen, and sulphur; it is consequently a nitrogenized body; it also possesses the power of contractility, which is in part due to the manner in which it is constructed.

What diseases affect joints? What are false cartilages? What wounds of joints are most dangerous? What is the color of muscle? Why are the pectoral muscles of fowls white? What chemical elements enter into the formation of muscle?

Fig. 37.

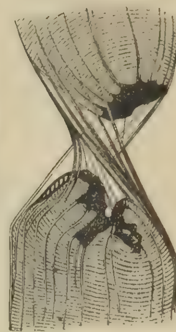
Blood-vessels of Muscular Tissue.

Fig. 38.



Rectangular Cells of Voluntary Muscle.

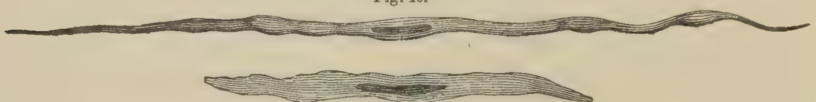
Fig. 39.



Striped Muscular Fibre.

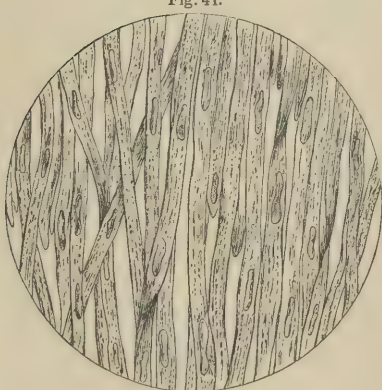
Muscles may be classified under two heads: the voluntary, controlled by the will, as the muscles of the extremities; and the involuntary, which act independently of the will, and even without its knowledge, as the muscular coat of the stomach and intestines. The microscopic characters of the two varieties are very different, voluntary muscle fibre being composed of rectangular-shaped cells, placed end to end like the cells of conferva, and having a rectangular nucleus. The fibres are

Fig. 40.



Involuntary Muscle Cells.

Fig. 41.



Unstriped Muscle.

formed into bundles, the arrangement of the cells being such that the nuclei are side by side, and form lines. Owing to this peculiarity, it is often called striped muscle.

Involuntary fibre, on the contrary, is composed of elongated cells, and there is no special system in their arrangement; consequently, the nuclei do not form lines, and it passes under the designation of unstriped muscle.

The force generated by the

What is the difference between voluntary and involuntary muscles, and the cells composing them?

Fig. 42.


OCCIPITO FRONTALIS
ORBICULARIS
PALPEBRARUM
TEMPORAL
ORBICULARIS
ORIS
MASSETER
STERNO-CLEIDO-MASTOID
BICEPS
TRICEPS
STERNUM
DELTOID
PECTORALIS
MAJOR
PECTORALIS
MINOR
RECTUS ABDOMINALIS
OBLIQUUS
EXTERNUS
GLUTEI
MUSCLES
RECTUS FEMORIS
SARTORIUS
ADDUCTOR
MUSCLES
RECTUS FEMORIS
BICEPS
FEMORIS
GASTROCHNEMIUS
TENDO
ACHILLIS

contraction of muscular fibre is applied to the bones through the intervention of an inelastic band of white fibrous tissue called tendon. One extremity of each fibre of a muscle usually arises directly from a bone, and the other terminates in the tendon, which passes over one or more joints, and is attached to another bone. The tendon is sometimes on the side of the muscle, giving an appearance similar to that afforded by an ordinary quill pen. These are called *penniform.* Sometimes fibres branch off from both sides of the tendon; such are *bipenniform.* In some muscles the fibres radiate from a central point, as in the iris of the eye; these are called *radiate.*

It is impossible, within the circumscribed limits of a text-book, to describe all the muscles of the body; but it is desirable that every educated person should know something regarding the names, position, and shape of the external muscles, which are situated immediately under the skin, and give to the body its beautiful contour and gracefully curved outline. Painters and sculptors endeavor to represent them in various works of art, and every one takes an honest pride in developing and exhibiting a graceful muscular limb.

The voluntary muscles may be described under six divisions, those of the head and neck, of the trunk, and the four extremities. The ends of the muscles are spoken of as the origin and insertion; the first is the portion in which the muscular fibres are attached directly to the bone; the insertion is the tendinous end; it is usually attached to the most movable bone.

The muscles of the head and neck are the occipito-frontalis, which lies immediately under the hairy scalp, extending from the eyebrows to the back of the head. Some persons possess the power of moving this muscle to a very considerable degree. Two muscles, the temporal and masseter, arise from the temporal fossa on the side of the skull, and are inserted into the ascending portion of the lower jaw; they give motion to the jaw, and are employed in the act of mastication. The cheeks are formed of a muscle called the buccinator. The muscle that forms the lips is the orbicularis oris; it is employed in the act of kissing, and consists of a number of circular bands that pass around the mouth. A similar circular muscle surrounds each of the eyes; it is called the orbicularis palpebrarum. The great muscle that forms the nape of the neck is the trapezius;

How is the force generated by muscles applied? What is a penniform muscle—bipenniform—radiate? Where are the largest muscles found? What are the divisions of muscles? What is the origin of a muscle? What is its insertion? What are the muscles of the head and neck? Describe their actions.

it throws the head back; it is opposed by the sterno-cleido-mastoid muscle, which bends the head forward on the chest. When both sets of muscles act together, the head is kept firmly fixed, as in carrying burdens. There are many other muscles in the head and neck, but these are the most prominent, and can be traced in the majority of paintings or pieces of sculpture.

The muscles of the upper extremities are the deltoid, triangular shaped, and covering the shoulder; it raises the arm from the side of the body to a horizontal position. The trapezius aids in carrying it up to the vertical line. The biceps, or large muscle on the front of the arm, flexes the fore-arm on the arm, and makes the preparation for striking a blow. The triceps extends the fore-arm on the arm; it is on the back of the humerus, and is used in delivering a blow. The muscles of the fore-arm are all small, and do not give any special marks or contours, except in persons in whom the muscular system is exceedingly well developed; we must therefore leave the description of them to more extended works on anatomy.

The muscles of the trunk are the pectoralis major and minor. They form the breasts, and, taking their origin from the sternum and inner edges of the upper ribs, are inserted into the humerus; they are employed in folding the arms across the chest. Opposed in action to the pectorals is the latissimus dorsi, which, arising from the lower two thirds of the vertebral column, is inserted into the humerus, and throws the arms backward; they are greatly developed by the exercise of rowing. The muscle which extends from the lower part of the sternum to the pelvis is called the rectus abdominalis. As is the case with nearly all the muscles of which we have treated, it is one of a pair; with its fellow it forms the anterior wall of the abdomen; it is divided transversely into three portions, the divisions being well marked only in very muscular individuals. The muscles which complete the walls of the abdominal cavity are the obliquus externus, obliquus internus, and transversalis. The fibres of these muscles are arranged, as their names indicate, so as to cross each other, and produce in their action an equable pressure on the organs contained in the abdominal cavity. In addition to these, there are a great number of small muscles in the back and between the ribs; the latter are called intercostals; they aid in carrying on respiration.

What are the muscles of the upper extremity? Describe their actions. Name the muscles of the trunk. Describe their actions.

Fig. 43.


OCCIPITO FRONTALIS
TEMPORAL
ORBICULARIS PALPEBRARUM
MASSETER
LARYNX
TRACHEA
TRAPEZIUS
DELTOID
HEART
DIAPHRAGM
BICEPS
STOMACH
GALL BLADDER
BLADDER
SARTORIUS
RECTUS FEMORIS
VASTUS EXTERNUS
VASTUS INTERNUS
PATELLA

The muscles of the lower extremities are, 1st. Those which form the buttocks; they are called the glutei muscles. They are arranged in three layers, viz., external, middle, and internal. Though these muscles exist in the lower animals, they are developed to a far greater extent in man, giving to him the power of retaining the erect position. Opposed to the glutei are the iliac and psoas muscles, which arise from the abdominal surface of the vertebral column, and, passing over the pubic bone, are inserted into the femur. The great muscles of the thigh are the rectus femoris, which passes from the iliac bone to the patella; the vastus externus and vastus internus, which take their origin from the outer and inner surfaces of the femur, and are inserted into the patella; they extend the leg on the thigh. The muscle which runs obliquely across the thigh, from the iliac bone to the inner edge of the tibia, is called the sartorius, or tailors' muscle, since it is employed in bending the lower extremities into the position assumed by persons of that trade while at their work. The muscles that are inserted into the patella are in reality attached to the tibia, for a strong ligament, about two inches in length, passes from the lower edge of the patella, and is attached to a rough surface on the anterior edge of the tibia. The largest muscle on the back of the thigh is the biceps; it flexes the leg on the thigh, and, since it takes its origin in part from the ischium, also aids in extending the thigh on the trunk. The muscles of the leg are the gastrocnemius, on the back of the leg, giving it its fullness; it extends the foot on the leg, and raises the body in walking. The tibialis anticus, and other smaller muscles on the front of the leg, flex the foot on the leg, and oppose the gastrocnemius.

The involuntary muscles will be described together with the organs and functions with which they are connected.

What are the muscles of the lower extremity? Describe their actions.

LECTURE VII.

ORGANS OF NUTRITION.

Fig. 44.

The Digestive Tract.

Divisions of the Nutritive Process.—Divisions of the Digestive Apparatus.—Distinctive Characters of Mucous and Serous Membranes.—The Composition and Classification of the Teeth.—Description of the Buccal Cavity.—The Pharynx.—The Œsophagus.—The Stomach.—The four Serous Membranes.—The Mucous Coat of the Stomach.—The Follicles of the Stomach.—The Ends of the Stomach.

Nutrition is divided into three distinct processes, viz., digestion, absorption, and circulation. We shall commence with the study of digestion, and the description of the anatomy of the apparatus by which it is accomplished.

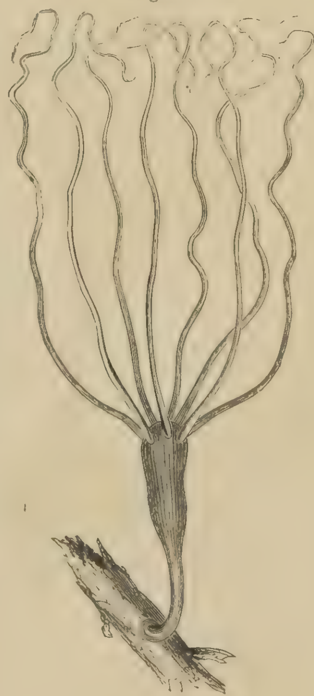
1, the tongue; 2, pharynx; 3, œsophagus; 4, soft palate; 5, section of larynx; 6, hard palate; 7, epiglottis; 8, thyroid cartilage; 9, spinal cord; 10, bodies of vertebræ; 11, 12, spinous processes; 13, cardiac end of the stomach; 14, splenic extremity; 15, pyloric end; 16, greater curvature; 17, lesser curvature; 18, the pyloric valve; 19, first portion of duodenum; 20, second portion; 21, third portion; 22, gall bladder; 23, cystic duct; 24, hepatic duct; 25, ductus communis choledochus; 26, its entrance into duodenum; 27, pancreatic duct; 28, 29, jejunum; 30, ileum; 31, open-

What are the divisions of the nutritive process?

ing of ileum into large intestine; 32, ileo-colic valve; 33, ileo-cæcal valve; 34, cæcum; 35, appendix vermiformis; 36, ascending colon; 37, transverse colon; 38, descending colon; 39, sigmoid flexure; 40, rectum; 41, anus.

For convenience of description, the digestive apparatus may be considered under six divisions: 1st. The mouth or buccal cavity; 2d. Pharynx; 3d. Œsophagus or gullet; 4th. Stomach; 5th. Intestines; 6th. Glands.

Fig. 45.



The Hydra.

The buccal cavity is closed in front by the lips, which are composed of muscle (orbicularis oris), and covered by mucous membrane. This membrane has a composition similar to that of the skin; it secretes a glairy fluid called mucus, and lines the digestive apparatus throughout its whole length, and may be described as being continuous with the skin. In some of the lower orders, as the polypes and hydra, it is not only continuous with the skin, but it also can at any time, by merely inverting the creature, be made to take on the action of the skin, while the skin becomes at the same time the digestive surface.

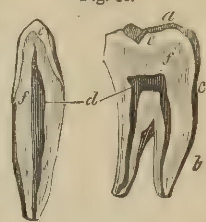
Mucous membrane is generally in the form of a tube, and communicates freely with the external air. When it is inflamed, the diseased condition terminates in the production of pus or matter. Serous membrane, on the contrary, is always in the form of a closed sac, and does not communicate with the external air. When inflamed, the disease usually results in the formation of adhesions which unite the surfaces of the sac together. Pus is very rarely formed, and when it is, it is a very unfavorable symptom, usually resulting in the death of the patient.

Immediately within the lips are the gums, composed of the alveolar processes of the maxillary bones, covered by thick mu-

What are the divisions of the digestive apparatus? Describe the buccal cavity. What are the properties of mucous membrane? What is the difference in form between mucous and serous membranes? What are the results of inflammation in both membranes? Describe the gums.

cous membrane. In the gums the teeth are fitted, their function being to masticate the food.

Fig. 46.



Parts composing Teeth.

The parts composing a tooth are the crown, *a*, which projects above the gums, *c*; the roots or fangs, *b*, which are fitted in the maxillary bones. The crown is covered by a dense, hard material, called enamel, *e*; while the bulk of the tooth consists of substantia ostoidea, or bone ivory, *f*. The cavity in the interior of the tooth is represented at *d*.

The substantia ostoidea closely resembles bone in its constitution, as is shown in the following table. The hardness of

Enamel.		Substantia Ostoidea.	
Organic substances.........	3.59	Organic substances.........	29.42
Inorganic "	96.41	Inorganic "	70.58

the enamel is also demonstrated to be due to the large amount of inorganic matter it contains. The cavity in the body of the tooth is filled with a fatty pulp, in which the blood-vessels and nerves subdivide before they enter the substantia ostoidea. From the great hardness and density of the enamel of the teeth, we should hardly expect to find that tissue supplied with so delicate a constituent as a nerve, but the presence of nerves in the enamel is demonstrated by the pain produced when a small hard substance, as a grain of sand, is entrapped between the teeth while masticating. The nerves gain access to the pulp through a canal in each fang; whenever, therefore, there is any inflammation either of the fang or of the crown, the substantia ostoidea is swollen, and, pressing upon the nerve, produces toothache, that most annoying of maladies. It must not be supposed, from the above statement, that toothache is always due to inflammation of the tooth, as it is more frequently a slight inflammation of the nerve itself, a true neuralgia of the nerves supplying the tooth. Toothache is sometimes very singular in its vagaries; for example, the disease may exist in a tooth in the upper jaw, and the patient will refer the pain to one in the lower jaw, and not be satisfied that he is mistaken until the wrong tooth is extracted, without obtaining relief from pain.

The mineral substances of which the teeth are composed are phosphate and silicate of lime and fluoride of calcium. They

What are the parts composing a tooth? What is the proportion of animal and mineral material in the enamel and sub ostoidea? What is the pulp of the tooth composed of? What are the causes of toothache? What are the mineral substances composing the teeth?

are constituents of the exterior covering of wheat and other cereals; consequently, in the finest varieties of flour, when the covering has been carefully separated, there is not a sufficient quantity of mineral substances to nourish the teeth properly, and we find the results in the defective teeth of the children of the wealthy, while those of the poorer class, who live on a coarser flour, have sound and perfect teeth.

A very common cause of bad teeth is the use of preparations of mercury in childhood. Such preparations seem to stimulate the growth of the teeth, and cause their projection above the gums before they have been properly covered with enamel, which is the natural protection of the substantia ostoidea against the action of the juices of the mouth.

There are two sets of teeth; the first is called the temporary or milk set, numbering twenty, which are loosely fixed in the jaw, and are shed at the sixth or seventh year; their roots being absorbed, and the teeth then pressed out of their sockets by the second or permanent set, which begin to appear when the jaw-bones commence to assume their final form.

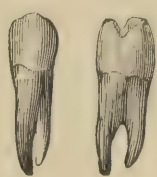
The permanent teeth are thirty-two in number, each half jaw containing two incisors or front teeth, one canine, two bicuspids, and three molars. The incisors have a single fang; they

Fig. 47.

Incisor Teeth.

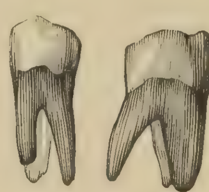
Fig. 48.

Canine Teeth.



Bicuspid Teeth.

Fig. 49.



Molar Teeth.

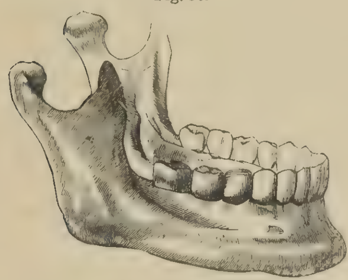
bite off the morsel of food. The canines also have a single fang, and are developed to a wonderful degree in animals that live entirely on flesh, and are regarded as an indication of the habits of the creature to which they belong—all animals that have canine teeth being carnivorous, or flesh feeders, while those that do not possess them are herbivorous, or vegetable feeders.

The bicuspids have two roots and a flat crown; they crush

From what sources are they derived? Describe some of the causes that produce defective teeth. What is the number of milk teeth? Why are they so called? How many permanent teeth are there? When do they appear? Into what classes are they divided? How many of each class in each half jaw? What do the canine teeth mark? How many roots have the incisors—canines—bicuspids?

the morsels that have been separated by the incisors. The molars have three roots and a large flat crown; they comminute the food as perfectly as possible, and put it in the most favorable condition for the action of the various digestive juices; they are developed to the greatest extent in herbivorous animals, enabling them to crush and subdivide the grain, twigs, or grass on which they feed. Animals that have the molars well developed do not possess canine teeth; and in those in which the canines are well developed, the molars are changed in character—become cutting instead of crushing in their action, and are called carnivorous teeth. From the examination of the teeth of man we find that the diet to which they are adapted is that which the experience of centuries has taught us is the best, viz., a proper mixture of animal and vegetable substances, his herbivorous wants being shown by his molar, and his carnivorous appetite by his canine teeth.

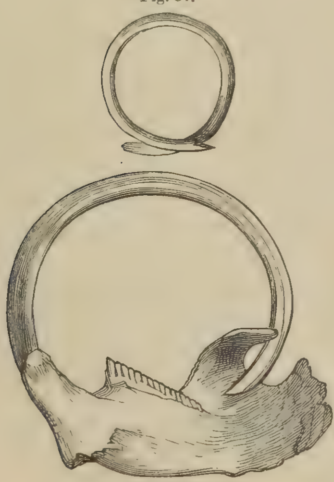
Fig. 50.



Human Lower Jaw.

In some animals the teeth grow with great rapidity, and are only kept of a proper size by being continually worn away by friction against the opposing teeth, as is demonstrated in *Fig.* 51, in which one incisor tooth of the upper jaw having been broken, that of the lower jaw which opposed it has grown to such an extent as to form a perfect circle, and finally caused death by interfering with the power of mastication, the jaws being locked together.

Fig. 51.



Jaw of Rat.

The order in which the teeth appear is as follows: incisors in the seventh and eighth year, canines in the eleventh, bicuspids in the ninth and tenth, and molars in the seventh, thirteenth, twentieth to thirtieth.

The sides of the mouth are formed by the cheeks; they are

How many roots have the molars? What inference may be drawn from the human teeth as regards diet? At what periods do the permanent teeth appear?

composed of the buccinator muscles, which are covered on the exterior by skin, and lined on the interior by mucous membrane.

The roof of the mouth is called the palate; the anterior portion consists of bone (palatal process of superior maxillary), covered by mucous membrane; the posterior portion is composed of muscles, covered by mucous membrane. The first is often called the hard, and the latter the soft palate.

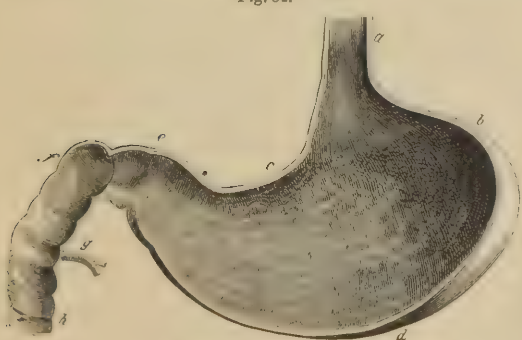
On the floor of the buccal cavity lies the tongue, being formed of muscle covered by mucous membrane; it is very freely supplied with nerves, and is the organ of taste.

On the sides of the back part of the cavity there are two small projecting teat-like organs called the tonsils; their function is not known; between them a similar process extends from the soft palate called the uvula.

The second division of the digestive tract is the pharynx; it is a pyramidal-shaped box composed of muscles, and lined with mucous membrane; it receives the mass of masticated food from the mouth, and forces it into the œsophagus.

The gullet or œsophagus is a tube formed of muscular fibre, and lined with mucous membrane; it extends from the pharynx to the stomach, passing down the neck and thorax in front of the vertebral column, and piercing the diaphragm in its course. The fibres of its muscular coat are arranged in such a manner that some pass around the tube, and others along its length. It forces the bolus of masticated food, by a species of vermicular movement, from the pharynx into the stomach.

Fig. 52.



Section of the Stomach.

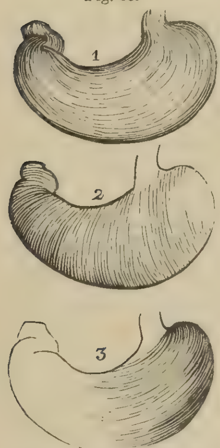
In the adjoining section of the stomach, *a* represents the œsophagus; *b*, the greater extremity; *c*, the smaller curvature; *d*, the greater curvature; *e*, the pyloric end; *f*, *h*, the duodenum; *g*, the entrance of the ducts of the liver and pancreas.

Describe the tissues composing the cheeks. What tissues form the palate? Describe the organs in the posterior part of the buccal cavity. Describe the pharynx. What tissues compose it? Describe the œsophagus. What tissues compose it? What is the course of the œsophagus? How does it act? Describe the position of the stomach.

The stomach may be described as a pear-shaped organ, lying in the upper part of the abdominal cavity, under the liver, and in the median line of the body, with the large end on the left side, and the lesser or pyloric end on the right; when it is empty it collapses, and occupies a very small space; but when it is distended either by food or gas, it can be made to hold about one gallon. The walls of the stomach are composed of three distinct membranes or layers, an interior coat of mucous membrane, a middle or muscular, and an external or serous layer.

The serous coat of the stomach is a portion of the peritoneum, or great serous membrane of the abdomen, which covers the interior walls of that cavity and all the organs it contains, enabling them to move readily over each other without friction during respiration and digestion. The other serous membranes are found covering the brain, lungs, and heart. The synovial sacs of the joints may also be regarded as belonging to this class of membranes.

Fig. 53.

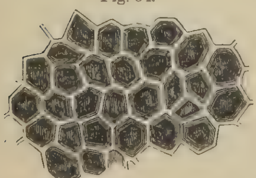


The Muscular Bands of the Stomach.

The muscular coat is composed of involuntary fibre, formed into bands or bundles, some of which run around the greater diameter of the organ (*Fig.* 53, 1), and others around the lesser, 2. Their duty is to cause the stomach to contract on its contents equally, or to impart to them a movement of rotation, by which they are mixed with certain juices, and digestion assisted.

The mucous coat has a special function to perform, viz., the secretion of the gastric juice; it therefore differs from the other membranes of the same class in being provided with a number of glove-shaped depressions or follicles. The interior of the follicles is lined with secreting cells, which form the gastric juice most actively when food is introduced into the stomach.

Fig. 54.



Mucous Membrane of Stomach, magnified 70 diameters.

The œsophagus enters the stomach at its large end; and, since the entrance is on the left side, and under the heart, it is

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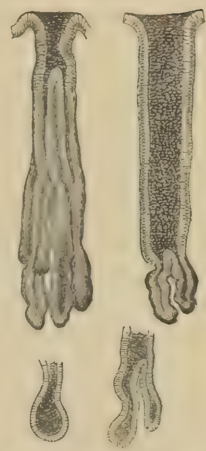
What is its shape—size? What tissues compose its walls? What is the peritoneum? Where are the other serous membranes found? What class of muscle cells compose the muscular coat of the stomach? What is the duty of the muscular layer? What is the function of the mucous coat? What are the follicles of the stomach? What is their function? Name the ends of the stomach. At which end does the œsophagus enter?

Fig. 55.



Sections of Stomach Follicles, magnified 150 Diameters.

called the cardiac opening. After digestion by the gastric juice is completed, the fluid formed escapes into the intestine through an opening at the opposite end, called the pyloric opening, which is closed by the pyloric valve. To this valve great importance was attached by the ancients, who even believed it to be the seat of the soul.

The coats of the stomach, and especially the mucous coat, are very freely supplied with blood-vessels, which are intensely congested during digestion. The supply of nervous force is also very large; one nerve in particular, the pneumogastric, which is derived directly from the brain, and passes through the thoracic cavity, giving branches to the lungs on its way, seems to have control of the movements of the organ, and also to influence the secretion of the digestive juice; for when it is cut or injured, the movements of the stomach cease, the gastric juice is secreted at a slower rate, and digestion is performed very imperfectly or not at all.

LECTURE VIII.

ORGANS OF NUTRITION—*Continued.*

Divisions of the small Intestine.—Coats of the Intestine.—Movements of the Intestine.—Valvulæ Conniventes.—Villi, their Composition.—Divisions of the large Intestine.—Appendix Vermiformis.

From the stomach the food passes into the small intestines, which are described as consisting of three divisions, viz., duodenum, jejunum, and ileum.

All the divisions of the small as well as of the large intestine are composed of three coats, like those of the stomach, viz., serous or peritoneal, muscular, and mucous. The external and middle are the same throughout the intestinal canal, the middle or muscular consisting of two sets of involuntary fibres, one of which passes around the tube, while the other runs along its length. When the muscular bands contract, a vermicular or worm-like motion is produced, which propels the contents of

What is the pyloric valve? Name the nerve of the stomach. Where does it take its origin? What is its function? What are the divisions of the small intestine? Name the coats of the intestine. What is the function of the muscular coat?

the tube downward. In perfect health, the motions of the stomach go on without our knowledge; but when the food is not properly digested, the contractions become more violent, and severe colic is produced. Sometimes the movements of the muscular bands are inverted, and the contents of the stomach and intestines forced upward, as in vomiting.

The internal mucous coat differs in the different parts of the canal, and may with advantage be considered with the description of each division.

Fig. 56.

The Duodenum.

The duodenum is eleven inches, or twelve finger-breadths in length; it is shaped like a horseshoe, so that its end lies under and a little behind its commencement. The mucous coat is velvety in character, the upper part for an inch or so from the pylorus being smooth or thrown into vertical folds. When these exist, they disappear in the second inch, longitudinal folds taking their place, which are called valvulæ conniventes, and their function seems to be to provide the necessary amount of membrane to enable the canal to be distended; it is also supposed that they may be of use in retarding the passage of the food down the intestine, and, by giving to it a movement of rotation, assist in completing digestion.

On the valvulæ conniventes there are minute projections, which may be seen by allowing a stream of water to run for a short time on a portion of the intestinal mucous membrane, to wash the mucus off, and then placing it in a saucer under water, when the villi are visible, giving to the membrane an appearance similar to that of cut velvet. These minute projections are found in the lower part of the duodenum and throughout the intestinal canal, but chiefly in the middle region of the small intestine.

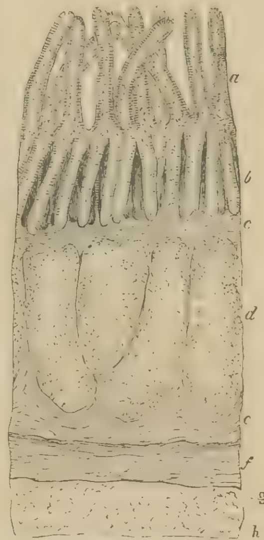
The second division is called the jejunum, because it is generally empty when examined. It is about ten feet in length;

Describe the duodenum. What is the course of the folds in the first part of the duodenum? Describe the valvulæ conniventes. What is their function? What gives the mucous membrane its velvety appearance? Where are the villi chiefly found? Describe the jejunum. What is its length?

in it the valvulæ conniventes are very prominent, and the villi numerous.

The third division, or ileum, receives its name on account of the intricate twists into which it is thrown; it also is freely supplied with valvulæ and villi, but they become less and less marked toward its lower extremity. The length of the ileum is about fifteen feet.

Fig. 57.



Section of Wall of Ileum magnified 50 Diameters.

In the figure the villi are represented at *a*; the glands of Lieberkuhn, *b*; muscular coat, *c*; follicles of Peyer, *d*; submucous tissue, *e*; circular muscular bands, *f*; longitudinal bands, *g*, *h*.

The total length of the small intestine is about twenty-six feet, and its diameter one inch. By some the duodenum is regarded as a species of second stomach, but, from the above statements, we find that there is no proper foundation for the opinion.

From the ileum the undigested food passes into the large intestine, the length of which is about six feet; adding this to the length of the small intestine, stomach, and œsophagus, we find that the total length of the digestive canal in a person six feet in height is thirty-four feet, or nearly six times the height of the body. The diameter of the large intestine is about three inches, and it is divided into six divisions, viz., cæcum, ascending, transverse, descending colon, sigmoid flexure, and rectum (see *Fig.* 44).

The cæcum is the commencement of the large intestine; it is on the right side of the abdominal cavity, and is separated from the ileum by a valve called the ileo-cæcal valve, which retards the passage of the portions of food that have not been properly digested in the small intestine. The cæcum is described as being pouch-like in form; it is attached by its exterior portion to the wall of the abdominal cavity, in the right iliac region, so that when the lower parts of the large intestine are closed by disease, and the fæces can not pass, a fistula or artificial communication may be made with the intestine in

Describe the ileum. How long is it? What is the length of the large intestine? What is its diameter? What is the total length of the digestive apparatus? What are the divisions of the large intestine? Describe the cæcum. What is its position? What valve separates it from the small intestine?

this region, and the life of the patient prolonged. This is sometimes done, though existence must be almost unendurable when we consider the discomforts and annoyances which attend the necessity of an artificial anus, as it is called.

To the anterior surface of the cæcum, a small worm-like tube, the appendix vermiformis, is attached; it is not of any use in man, though it is developed to an enormous extent in some animals and birds, becoming one of the important divisions of the digestive canal, and reaching in the ostrich a length of nearly three feet.

Though the appendix is merely rudimentary in man, and has no special duty, it is by no means to be overlooked or disregarded, for it often happens that an undigested hard substance, like a cherry-stone, is by some accident caught in the mouth of the appendix, and originates an inflammation similar to that produced by a splinter in the skin; this may continue for months, and I know of one instance in which a cherry-stone was impacted in the appendix, and remained there for many years, producing epileptic convulsions, and finally caused death by perforating the intestine, and passing into the cavity of the peritoneum, where it was found on making a post-mortem.

The second division of the large intestine is the ascending colon; it passes up on the right side, and terminates in the transverse colon, or third division, which crosses from the right to the left side, lying immediately under the stomach; reaching the left side, the colon curves downward to form the fourth division, or descending colon, which, in the left iliac fossa, becomes an S shaped curve called the sigmoid flexure, or fifth division. The end of this flexure, or bend of the large intestine, lies in the upper part of the pelvic cavity, opposite the superior surface of the sacrum; from this point the intestine passes downward, following the concavity of the sacrum, and forming the sixth division or rectum, which is closed below by a band of voluntary muscular fibre that forms the anus or opening.

The coats of the large intestine are the same as those of the jejunum, but less freely supplied with villi. Certain glands are also found in this part of the digestive mucous membrane, which will be hereafter described.

What is an artificial anus? What is the appendix vermiformis? What is its function? Under what circumstances is the appendix dangerous? Where is the ascending colon? Where is the transverse colon? Where is the descending colon? Where and what is the sigmoid flexure? What are the coats of the large intestine?

LECTURE IX.

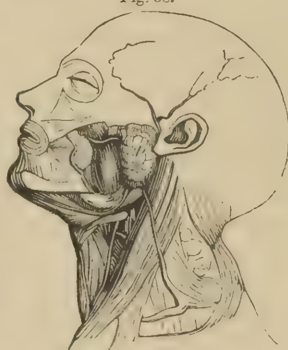
ORGANS OF NUTRITION—*Continued.*

THE GLANDS.

Buccal Glands.—Description of the Salivas.—Properties of mixed Saliva.—Nature of Ferments.—Abdominal Glands.—Duty of the Liver.—Nature and Properties of Bile.—The Pancreas.—Nature and Properties of its Secretion.—Origin and Properties of Gastric Juice.—Uses of Pepsin.—Origin and Properties of Intestinal Juices.

After the food has been properly subdivided, it is mixed with certain juices which are secreted by glands. The glands are arranged under the following heads: 1st. Those of the buccal cavity; 2d. Those of the abdominal cavity.

Fig. 58.



Parotid Gland.

The glands of the buccal cavity are the parotid, submaxillary, and sublingual; they are also called the salivary glands. The parotid gland, *p*, is beneath the ear, and behind the lower jaw on each side; its secretion is conveyed to the mouth by means of Steno's duct, *s*, which crosses the buccinator muscle, and pierces it near the centre, delivering the saliva into the mouth opposite the second molar tooth, so that it is mingled with the food while it is being masticated by the teeth; it is well adapted to the purpose of forming a pasty mass with the food, for it contains more water than any other saliva.

The submaxillary glands are behind the horizontal part of the inferior maxillary bone; their secretion is more consistent than that of the parotid gland, and is conveyed to the mouth by Wharton's duct, which opens close to the bridle of the tongue. The sublingual glands are under the tongue on each side of the bridle; their secretion is delivered by fifteen or twenty ducts, which perforate the mucous membrane of the

Into what classes are the glands divided? Name the glands of the buccal cavity. Describe the position of the parotid gland. What is the name of its duct? What is its course? What is the function of parotid saliva? Where is the submaxillary gland? What is the name of its duct? Where does it enter the mouth? Describe the sublingual glands.

floor of the mouth. The function of submaxillary and sublingual saliva is to coat the food with a slimy material, which facilitates its passage into the stomach.

The secretion of the glands of the buccal cavity, together with that of the mucous membrane, is called mixed saliva; it is alkaline in its reaction, turning red litmus blue. The constituent which produces this result is free lime, as is shown by the pellicle of carbonate of lime which forms on the surface of saliva that is allowed to stand in the open air. The total amount of saliva secreted in twenty-four hours is fifteen or twenty ounces, but it depends to a great extent on the excitement to which the glands are subjected. During the mastication of food, or in speaking, the secretion is greatly increased; mental impressions produce a similar result, as the expectation of a good meal, or the odors given off during the cooking of various savory dishes.

One of the most important ingredients of saliva is a nitrogenized body called ptyaline; it belongs to the class of ferments which possess the power of causing other substances to undergo change with more or less rapidity. Each of the digestive juices contains a ferment, and they seem to be essential to the proper performance of digestion. They are all bodies which may be said to be in the act of undergoing final decomposition; and it is one of the most beautiful illustrations in the whole domain of physiology of the manner in which materials are consumed, that the dying, effete nitrogenized substances which are no longer of any use in the system should, in being cast out, aid in the introduction of new nutritive materials, teaching us the lesson that in the laboratory of nature nothing is lost, nothing is wasted.

The slimy nature of the submaxillary and sublingual juices also causes a considerable amount of air to be entrapped with the food and carried into the stomach, where it assists the digestive juices in dissolving the food.

The abdominal glands connected with digestion are the liver, pancreas, stomach follicles, and intestinal glands.

The liver is the largest gland in the body, its weight being four pounds; it lies immediately under the stomach, and is held in position by ligaments formed of folds of peritoneum.

What is the function of submaxillary and sublingual saliva? What is the reaction of mixed saliva? What substance gives it this reaction? How much saliva is secreted in twenty-four hours? What causes influence the production of saliva? What is the ferment of saliva? What is the composition and nature of ferments? What special function does submaxillary saliva perform? Name the abdominal glands. What is the weight of the liver? Describe its position.

It is divided into two large lobes, the right being the largest; in addition to these, anatomists mark out two or three smaller lobes. It is freely supplied with blood by arteries, and also receives through a short trunk, called the portal vein, the blood from all the other organs in the abdomen except the kidneys. The gall-bladder is attached to the under surface of the liver, and serves as a reservoir in which the excess of bile is retained until it is required for use.

Fig. 59.

The Liver.

In the adjoining figure the right and left lobes are represented, together with the blood-vessels of the organ and the gall-bladder.

The liver separates bile from the blood, and empties it, by means of the hepatic duct, into the intestine. If we examine the blood before it enters the organ and as it passes out, we find that sugar has been formed, and a certain quantity of fat has disappeared, showing that another very important duty of the liver is the transformation of fat into sugar, and that it is intimately connected with the function of respiration. It also produces a peculiar fat called cholesterine, which is employed as an external covering of nervous fibres.

Bile is a yellow or green fluid, with an alkaline reaction, due to the presence of free soda. It is not formed in the liver, but in the blood, the liver merely filtering it out from that fluid. The total amount secreted in the course of a day is fifty-four ounces. It is the natural stimulant of the intestines, as is shown by the fact that when it is deficient in quantity the intestines act in a sluggish manner, and only resume their energy again when the secretion of bile is increased either naturally or by the use of medicines.

It has been supposed by some physiologists that bile was an important agent in the digestion of the food, but this opinion is in a great degree controverted by the fact that the secretion of this juice is most rapid about thirteen hours after the chief meal of the day, and at the time when the intestinal action is most energetic in the endeavor to remove the undigested materials to the lower part of the digestive canal.

From what sources does it receive blood? Where is the gall-bladder? What is its function? What is the duty of the liver? What change is impressed on the blood during its passage through the liver? What is cholesterine? What is its function? Describe bile and its properties. Where is it formed? What is the diurnal amount of bile? What is its function? At what time is bile secreted in largest quantity?

Fig. 60.

The Pancreas.

The pancreas is represented at *o* in the adjoining figure, *g* being the gall-bladder; *s*, the cystic duct; *c*, the ductus communis choledochus; *p*, the pyloric valve; *e é*, the duodenum; *i*, the termination of the duodenum.

The pancreas resembles the salivary glands in its structure; it varies in size, weighing from two to five ounces. It lies in the curve of the duodenum, across the vertebral column. The duct commences at the small end, and, passing out at the head of the gland, unites with the ductus communis before it pierces the intestine.

The common duct of the liver and pancreas is about the diameter of a goose-quill; it enters the duodenum near the centre of the middle portion, passing through the coats in an oblique manner, forming a valve.

The diurnal secretion of the pancreatic fluid is about thirty ounces; it is alkaline in its reaction, owing to the presence of soda; its ferment is called pancreatine. The special function of pancreatic fluid is to digest fatty bodies, as is demonstrated by the fact that when the pancreas is diseased, these substances are not digested, but pass out in the fæces.

The stomach follicles have been described in the discussion of the mucous membrane of the stomach. They secrete a fluid called the gastric juice; it has a strong acid reaction, owing to the presence of hydrochloric acid, which is formed by the decomposition of common salt in the presence of water, as is expressed by the adjoining symbols, which also demonstrate that soda is at the same time produced, and, as we have seen, makes its appearance in the bile and pancreatic fluid.

Common Salt...... {Na, Cl} — NaO, Soda.

Water................ {H, O} — HCl, Hydrochloric acid.

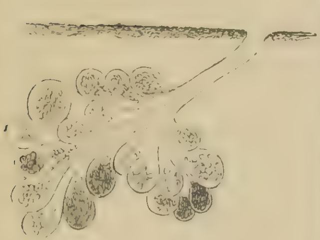
The ferment of the gastric juice is called pepsin; it may be collected in quantities from the stomach of the calf for the pur-

Describe the pancreas; its weight; position. What is the course of its duct? What is the diurnal amount of pancreatic fluid? What is its special function? What is the reaction of gastric juice? To what substance is its reaction due? Explain the origin and formation of the acid. What is the ferment of gastric juice?

poses of experiment; its function, as we shall fully demonstrate hereafter, is to aid the acid in dissolving certain articles of food.

The intestinal juice is secreted by a number of glands, classified as, 1st. Brunner's, which are about the size of hemp-seeds, and scattered throughout the intestines, but are chiefly found in the mucous membrane of the upper part of the small intestine; 2d. The follicles of Lieberkuhn, which resemble the stom-

Fig. 61.

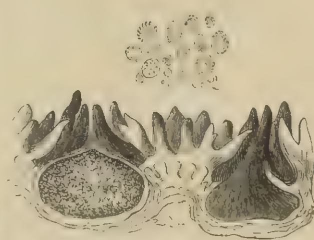


Brunner's Glands.

Fig. 62.

Follicles of Lieberkuhn.

Fig. 63.



Peyer's Plates.

ach follicles; they are also found in all parts of the intestinal mucous membrane; 3d. Peyer's plates, which are circular glands without ducts, and found in the lower part of the small intestine and the colon.

The intestinal juice is acid in its reaction, and contains a ferment similar to pepsin; it acts upon the same articles of food as the gastric juice, dissolving those portions which have escaped stomach digestion.

LECTURE X.

FOOD.

Annual Amount of Food consumed.—The Ingesta.—The Introduction and Use of Water in the System.—Latent Heat of Vapor of Water.—Variation in the Food of different Nations.

Having completed the study of the various parts of the digestive apparatus, we are prepared to examine into the duties of each portion; for, as the characters of the juices in the dif-

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What is the function of pepsin? What is the source of the intestinal juice? Describe Brunner's glands. What are Lieberkuhn's follicles? What are Peyer's plates? What are the properties of intestinal juice?

ferent divisions of the digestive canal differ, so also do they differ in their action, some articles being digested by one juice and not by others.

That man is a destructive machine is abundantly proved by the fact that in the course of a year he takes into his system more than three thousand pounds of materials; and, since the weight of an adult does not increase, a similar amount must also be voided. The materials introduced are called the ingesta, those voided are called egesta.

The ingesta may be classified under the following divisions, the amount of each class having been obtained from the army and navy ration-scales of different nations, and by experiment:

Annual Ingesta.

Water	1500 lbs.
Food	800 "
Air	800 "
	3100 "

The egesta also amount to 3100 pounds, and consist of expired air, perspiration, urine, and fæces.

Water may be introduced into the system by immersing the body in a warm bath, after which it will be found to have increased in weight, the amount of increase depending upon the previous abstinence from the use of liquid. It is stated that shipwrecked sailors, whose bodies are exposed to continued contact with water, do not suffer thirst, the liquid being introduced through the vessels of the skin.

The uses of water in the system are, 1st. To form the food into a solution, so that it can be taken up by the vessels which are intended to absorb the fluids produced by digestion; 2d. To form the basis of all the circulating juices of the body; 3d. To keep down the temperature of the body to 98°; and, 4th. To carry effete or oxidized substances out of the system in solution.

In order to appreciate how powerful an agent water is in controlling the temperature of the body, we have only to examine into the change it undergoes in being converted into vapor or steam. If we take a given quantity of water and subject it to the action of heat in such a manner that the temperature of the mass shall rise one degree per minute, we find that it will follow the law until it reaches 212°, when the temperature no

What is the annual amount of ingesta? What are the egesta? What are the divisions of the ingesta? What is the amount of each? What are the divisions of the egesta? How may water be introduced into the system? What are the functions of water in the system? How does water control the temperature of the body?

longer rises, but remains at that point until the liquid has all evaporated as steam, which requires 1000 minutes. If we place a thermometer in the steam as it rises from the water, we find that its temperature is the same as that of the liquid, although it has absorbed all the heat that was passing into it for 1000 minutes. From this and other experiments, we find that steam differs from water in containing 1000 degrees of heat in a latent or hidden form that is not appreciated by the thermometer; consequently, the total amount of heat in boiling water being 212°, that contained in the steam rising from it is 1212°.

Applying the above facts to the explanation of the results produced by the evaporation of water from the skin and lungs we find that the vapor of water, which is continually rising from the surface, conveys away the excess of heat that has been generated during the performance of the various functions of the different parts of the body.

Water, food, and air constitute the ingesta of all men in all parts of the world. Of these, water and air present but very slight modifications or variations; they may therefore be regarded as invariable in their character. But this is not the case with food. The Esquimaux or Laplander will devour an enormous amount of oil or whale blubber, and would at any time prefer a lump of tallow to the most daintily-served entrée, while the West Indian can hardly be induced to eat any fat substance, but delights in fruits with which nature generously supplies him in great variety.

LECTURE XI.

DIVISIONS OF FOOD.

Milk, its Composition and Variations.—The nitrogenized Group.—The non-nitrogenized Group.—Hydro-carbons.—Carbo-hydrates.—Fermentation of Starch and Sugar.—Influence of Temperature on Fermentation.—Composition of Flour.—Bread-making.—Wine-making.—Use of Phosphate of Lime.—Of Chloride of Sodium.

Though the diet of adults may be variable, such is not the case with the newly-born infant, for milk presents a uniform constitution as regards the nature of its ingredients, though their proportions may vary.

What is meant by latent heat? What is the latent heat of steam rising from boiling water? How does the evaporation of water influence the temperature of the body?

Composition of Milk.

Water	873	
Casein	48,	Nitrogenized and nutritive.
Sugar	44	Respiratory and non-nitrogenized.
Butter	30	
Phosphate of lime	2.30	Salts.
Salt	2.70	
	1000.00	

The milk of the human female varies but little in its composition, though it is said that the milk of the brunette is richer than that of a blonde. The animal milk that approaches more nearly in character to human milk than any other is that of the ass; it therefore follows that it is better adapted to the nourishment of the human infant than any other form of diet except the natural supply. Owing to the difficulty of obtaining asses' milk, cows' milk is generally substituted; but it is so much stronger than human milk, that it must be diluted with three or four times its volume of water, and sufficient sugar added to make it sweet to the taste; it then forms an excellent substitute. But if it is not properly diluted, it often disagrees with the child, giving it diarrhœa, and finally causing death. I have frequently been surprised at the want of information that exists among mothers, and even among physicians, regarding the above simple facts; and have aided in producing the recovery of infants that have been wasted away to mere skeletons, by simply directing attention to their diet, and causing the milk which had been given in the undiluted state to be properly reduced with water, in order to adapt it to the digestive powers of the child.

The second component in order of quantity is casein, which furnishes the curd when the fluid turns sour, and is the material that forms cheese. It is composed of the chemical elements, carbon, hydrogen, oxygen, and *nitrogen;* it is therefore called a nitrogenized substance, and is one member of an important division of food, the others being, 1st. Fibrin, which possesses the power of self-coagulation; it is formed in the blood, and is employed in nourishing muscular tissue, of which it is the chief constituent; 2d. Albumen, also found in blood, but existing in a purer state in the white of eggs; it does not coagulate spontaneously, but can be made to assume the solid form either by heating to 180° F., or by adding certain acids or other chemical agents; 3d. Gluten, or vegetable fibrin, may

What are the ingredients of milk? Does human milk vary in its composition? What variety of milk resembles human milk? Is cows' milk suitable for infants? What is casein? To what group of food does it belong? What are the other members of the nitrogenized group? What are their properties?

be obtained from any plant, or from the flour of various seeds.

Professor Playfair says, "Vegetables are the true makers of flesh; animals only arrange the flesh which they find ready formed in animals and plants. If we go farther down in the chain, we find all food in the *débris* of rocks, for the breaking up of these form the earth, from which it is eliminated by the chemistry of plants, to be farther sorted for man's use in the bodies of animals. We thus see how significant and literally true is the term we apply to the earth of 'our great mother.'"

The nitrogenized bodies, albumen, fibrin, casein, and gluten, are also called nutritive and histogenetic (tissue building), since they are employed in nourishing all the tissues of the system to a greater or less degree. They may be dissolved without difficulty, and formed into a fluid solution by dividing them into small pieces, and keeping them for several hours in dilute hydrochloric acid, the temperature of which is maintained steadily at 150° to 200°.

If to the mixture of acid and nitrogenized substances a little pepsin is added, the action then goes on at a temperature of 100° as rapidly as at 200° without the pepsin; from which we conclude that the ferment impresses some change on nitrogenized substances, which enables the acid to dissolve them at a temperature as low as that of the stomach, viz., 102° to 104°.

Butter and sugar form a very considerable portion of the solid constituents of milk. They are composed of hydrogen, carbon, and oxygen, and do not contain nitrogen; they are therefore described as non-nitrogenized bodies. They are employed in the system as combustibles, by the burning of which the animal heat can be maintained; consequently they are often spoken of as calorifacient or respiratory food.

The non nitrogenized bodies are subdivided into two classes, owing to the difference in the quantity of the elements they contain; and since the subdivision has a practical value in the study of the digestion of respiratory substances, we shall devote a few lines to its consideration.

Butter, fat, and all oily bodies contain an enormous amount of carbon, hydrogen, and but very little oxygen; they are therefore called hydro-carbons, and constitute the first subdivision. The amount of oxygen they contain being so small,

What other names are given to the nitrogenized group? How may nitrogenized substances be dissolved? At what temperature? How does pepsin influence the action? What substances form the non-nitrogenized group? What other names are given to this group? What are its subdivisions? What are the peculiarities of the hydro-carbons?

they can in a given weight furnish a far greater amount of heat during their combustion in the body than can be obtained from the same weight of sugar.

Sugar, starch, gum, and similar substances contain hydrogen and oxygen in equal proportions, so that the hydrogen may be regarded as useless, since it is already united with as much oxygen as it has affinity for, and the carbon only is available for the production of heat. The proportion of carbon in this group is also very small, the number of atoms being about equal to the number of atoms of hydrogen. Owing to the proportions in which the constituents exist, it has received the name of the carbo-hydrate division.

If sugar is mixed with saliva, and kept at a temperature of 100°, it undergoes a change, the sugar gradually disappearing, and lactic acid taking its place. Starch also undergoes a change when brought in contact with saliva, first being converted into glucose, a species of sugar, and finally into lactic acid. These changes are due to the action of the ptyaline of the saliva, and belong to the class of phenomena included under the head of fermentation, the study of which is necessary in order to understand the digestion of the carbo-hydrates.

Fermentation is not only of interest in connection with the mere act of digestion of starch and sugar, but, since it lies at the basis of such operations as bread-making and wine-making, it becomes doubly interesting to the student.

In order, to produce the fermentation of sugar, a solution of the substance should be mingled with some suitable decaying nitrogenized ferment. Nothing answers the purpose better than yeast. Placing such a mixture in a cool place, where the temperature does not rise above 70°, it after a while takes on an internal movement, attended by the evolution of a considerable amount of gas.

If the gas is collected, and examined by suitable tests, it is found to be composed of carbonic acid; and if the liquid is submitted to distillation after the fermentation has ceased, it is found to contain a large quantity of alcohol. This is the case so long as the temperature is kept below 70°; if it is allowed to rise above that degree, and approach 90° or 100°, carbonic acid and alcohol are no longer produced, but lactic acid takes

What substances form the carbo-hydrate group? What are their peculiarities? Which group of respiratory food furnishes the greatest amount of heat? What is the action of saliva on sugar—on starch? What is the cause of the action? Upon what action do wine and bread making depend? Describe the fermentation of sugar at 70°. What gas is evolved at this temperature? What is produced besides carbonic acid? What are the products when sugar ferments above 70°?

their place. Temperature, therefore, has a controlling influence over the fermentation of sugar, and decides whether it shall undergo the lactic or the alcoholic fermentation.

From the above facts, we see why it is that the wine-maker resorts to the use of underground cool vaults in carrying on his business; he knows that if the temperature should even for a short time rise above a certain degree, the whole vat of juice would be lost, and vinegar produced instead of wine.

In the fermentation of starch the effect of temperature is as marked as in the case of sugar; but lactic acid is produced below 70°, and alcohol and carbonic acid above 70°.

Starch is contained in all varieties of flour, as may be readily shown by taking a small quantity and making it into dough by the addition of a little water. If the mass of dough is then kneaded under the surface of water, a fine powder is slowly washed out, which sinks to the bottom of the vessel, and a tenacious mass remains in the hand, which is the gluten of the flour.

In the making of bread a certain degree of porosity is to be obtained, which renders it more digestible. This is accomplished by forcing the starch to undergo fermentation, the process consisting in taking a given quantity of flour, mixing it with water and yeast, and setting it aside in a warm place until fermentation is thoroughly established. More flour is then added, the mass worked up, divided, and set aside for the fermentation to continue for a short time; it is then placed in an oven at a temperature of about 400°. The high temperature stops the fermentation, and is applied long enough to drive off the excess of water and the alcohol that has been produced. The bread is then said to be baked.

If the temperature of the dough is allowed to fall below 70°, the lactic fermentation sets in, and the bread turns sour. It is then unfit for use, since mastication converts it into a paste, the interior of which the digestive juices can not penetrate.

In the Kensington Museum there is a case containing different varieties of bread, which presents some facts of interest. Among the specimens exhibited there is a loaf of ordinary fermented bread, two years old, which is converted into a mass of green fungus, while the samples of unfermented bread of the same age are perfectly free from any such growth.

In the same case there are specimens of New Zealand bread

What are the products of fermentation of starch above and below 70°? What is the composition of flour? Describe the chemistry of bread-making. What is accomplished in baking bread? Why must the dough be kept in a warm place?

made of the pollen of a reed; also Dika bread, from Africa, which has the appearance of Castile soap when cut. There is also a specimen, said to have been found in Lake Zurich, and supposed to belong to the stone period, but there are doubts regarding its history.

The salts are phosphate of lime and chloride of sodium, or common salt. The first is employed in the nutrition of the bones, and the second, as we have seen, is essential to the proper conduction of digestion, furnishing hydrochloric acid for the gastric juice, and soda for the bile and pancreatic fluid.

LECTURE XII.

DIGESTION.

Mastication.—Action of Saliva.—Action of Gastric Juice.—Formation and Properties of Chyme and Chyle.—Action of Pancreatic Juice on Hydro-carbons and Carbo-hydrates.—Old and new Theories of Digestion.—Digestibility of various Articles of Food.—Effect of Quantity on the Rate of Digestion.—Indigestion as a Disease and a Symptom.—Effect of Nature of Diet on Length of Intestine.—Digestive Apparatus in certain Animals.

Having described the digestive apparatus, and examined into the nature of the ingesta and digestive juices, we now pass to the detailed explanation of the processes to which the food is subjected before it is properly prepared for absorption by the blood-vessels and lacteals.

The first operation to which it is submitted is mastication, during which it is not only thoroughly subdivided, but also mixed with saliva and air. It is then swallowed, and, passing into the stomach, the ptyaline of the saliva commences immediately at the existing temperature to convert starch into glucose or sugar, and then into lactic acid. While this is going on in the interior of the mass, the gastric juice is acting with energy on its exterior, the hydrochloric acid, by the aid of the pepsin, dissolving the nitrogenized substances, albumen, fibrin, casein, and gluten, converting them into soluble peptones. Gradually, by the agency of the saliva and gastric juice, the mass is broken up, and a fluid called chyme produced, which is of a tawny yellow color, and contains the oils and fats undissolved.

What is the use of phosphate of lime? For what purpose is chloride of sodium employed in the system? What is accomplished by mastication? What is the action of the gastric juice? Where is its action carried on? What are peptones?

The saliva is indirectly very efficient in promoting true gastric digestion, that is, in dissolving substances of the nutritive group; for the product of its action on starch and sugar is lactic acid, which attacks and dissolves nitrogenized bodies almost as readily as hydrochloric acid. While, therefore, the acid of the gastric juice is acting on the exterior of the mass in the stomach, the lactic acid, which is being continually produced in its interior, is also assisting in the formation of a solution.

In persons who swallow their food without proper mastication, the saliva is not thoroughly mingled with it, consequently lactic acid is not formed in sufficient quantity; the whole duty of gastric digestion is thrown on the gastric juice; it takes a longer time to accomplish the solution of the food, and the person suffers from an indigestion for which there is no cause but indolence, unless the teeth are so imperfect that mastication can not be properly performed.

From the stomach the chyme oozes little by little through the pyloric valve into the duodenum, where it meets the pancreatic fluid and bile, and quickly, under their influence, becomes converted into a milky fluid, to which the name of chyle is given.

Chylification consists in converting the oils and fats into an emulsion, so that they can be dissolved or suspended in water. If soda is added to any fatty substance in sufficient quantity, it unites with it to form a soap, in which state it is soluble in water; but the pancreatic fluid contains albumen as well as soda, and each minute globule into which the oil or fat has been divided by the soda is covered with an extremely thin layer or covering of albumen, forming an emulsion, in which condition the fat can be introduced into the absorptive mechanism, and finally reach the blood.

Pancreatic juice not only converts the fats and oils into an emulsion, but it also acts on starch and sugar with even greater energy than saliva, its pancreatine forcing them to undergo the lactic fermentation with great rapidity. Owing to this property of the pancreatic fluid, nearly all the particles of starch or sugar that have escaped the action of saliva are digested by pancreatic juice, and converted into lactic acid in such quantity that the alkaline reaction of the fluids of the duodenum is lost when the lower part of the small intestine is

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How does saliva assist the gastric juice? What is the effect of bolting the food? Where and by what juice is chyme converted into chyle? What is meant by chylification? What is the difference between an emulsion and a soap? What is the action of pancreatic juice on carbo-hydrates?

reached, an acid reaction taking its place, and continuing throughout the large intestine.

The juices of the intestinal glands are acid in their reaction. The mixed juice contains a ferment, probably derived from the follicles of Lieberkuhn; it acts on nitrogenized bodies, dissolving them with ease, and completes the digestion of those portions of nutritive food which have escaped the action of the gastric juice in the stomach.

The above account of digestion is now generally accepted as the true explanation of that function. Among the various opinions that have been held regarding it, we may mention the mechanical hypothesis which supposed that the food was dissolved by a species of grinding operation by the walls of the stomach. This was finally overthrown in favor of the chemists by taking various articles and shutting them up in spherical silver balls, the walls of which were perforated, to allow the gastric juice free access to their contents. On giving them to dogs to swallow, and then withdrawing them from time to time (by means of a string attached in a proper manner), and examining their condition, it was found that the contents of the spheres were slowly dissolved, showing that mechanical action was not essential, though it might assist digestion.

Every person knows, by his own experience and by the statements of friends, that certain articles of food are more readily digested than others. The comparative digestibility of ordinary articles was determined by Dr. Beaumont, who had a patient, Alexis St. Martin, in whose abdomen there was an opening that communicated with the stomach, and which was the result of a gun-shot wound.

Beaumont states that when the stomach was empty, the mucous membrane was of a pale color; but when food was introduced, it immediately assumed a bright pink tint, owing to the congestion of the blood-vessels, and in a few moments the mouths of the follicles were marked by small lucid points, caused by the flow of gastric juice.

The gastric juice exuded with equal freedom both when the food was introduced by the mouth or by the opening in the abdominal walls through which the observations were made.

What is the reaction in the upper and lower parts of the intestine? What is the reaction of the intestinal juices? What do they accomplish? What was the old theory regarding digestion? How was the mechanical theory disproved, and the chemical established? How was the digestibility of various substances determined? What is the color of the gastric mucous membrane before and after the introduction of food? What is the appearance presented by the mouths of the follicles?

If the following table, furnished by Beaumont, is carefully examined, it will be noticed that the method of cooking also influences the rate of digestion, fried articles being more indigestible than those which are roasted or boiled.

Table showing the Time required for the Digestion of various Articles.

	h. m.		h. m.
Apples, sweet, raw	1 30	Milk, boiled	2 00
" sour, mellow, raw	2 00	" raw	2 15
Beans, pod, boiled	2 30	Mutton, fresh, roast	3 15
Beef, fresh, rare, roasted	3 00	" " broiled	3 00
" " dry, "	3 30	" " boiled	3 00
" " fried	4 00	Oysters, fresh, raw	2 55
Beets, boiled	3 45	" " roast	3 15
Bread, wheat, fresh baked	3 30	" " stew	3 30
" corn, " "	3 15	Parsnips, boiled	2 30
Butter, melted	3 30	Pork, fat and lean, roast	5 15
Cabbage with vinegar, raw	2 00	" " broiled	3 15
" boiled	4 30	" " raw	3 00
Catfish, fried	3 30	Potatoes, Irish, boiled	3 30
Cheese, old, strong, raw	3 30	" " baked	2 30
Codfish, cured dry, boiled	2 00	Rice, boiled	1 00
Corn, green, and beans, boiled	3 45	Sago, "	1 45
Custard, baked	2 45	Salmon, salted, boiled	4 00
Ducks, domestic, roasted	4 00	Soup, beef, vegetable	4 00
" wild, roasted	4 30	" chicken, boiled	3 00
Eggs, fresh, hard boiled	3 30	" oyster, boiled	3 30
" " soft "	3 00	Tapioca, boiled	2 00
" " fried	3 30	Tripe, soused, boiled	1 00
Flounder, fresh, fried	3 30	Trout, salmon, fresh, boiled or fried	1 30
Fowl, boiled	4 00	Turkey, domestic, roast	2 30
" roast	4 00	" wild, roast	2 18
" fricasseed	2 45	Turnips, boiled	3 30
Goose, roast	2 00	Veal, fresh, broiled	4 00
Lamb, fresh, boiled	2 30	" " fried	4 30
Liver, beef, boiled	2 00	Venison steak, broiled	1 35

The rate of digestion depends on the quantity as well as the quality of the food, for Beaumont found that while one egg was digested in one hour, it required four hours to digest eight eggs. The digestion of soups is often very imperfect unless they are mixed with some such substance as bread, to retain them in the stomach, and prevent their passage into the duodenum until they are properly prepared for absorption.

We can not leave the consideration of the function of digestion without making a few remarks on indigestion, that most obscure of maladies. If we examine any of the works on hygiene, we find them stored with very valuable information regarding the manner in which indigestion is to be prevented. Among these there are careful directions regarding the articles which persons so troubled should avoid. But I have found, in a hospital experience of more than two years, that such rules

What method of cooking furnishes the most digestible food? What is the effect of quantity on the rate of digestion? How may soups be made to digest perfectly? Give some of the theories regarding indigestion, and the methods for palliating it.

can not be established, for some patients would digest with ease articles which were considered the most indigestible, and which would give an attack of colic to any healthy person, while a meal of substances usually regarded as very digestible would subject them to hours of torture.

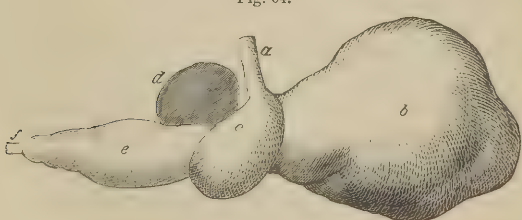
Some physiologists advise that the water introduced into the system should always have a temperature approaching that of the stomach; but it is almost impossible to follow such a plan, especially when we recall the nauseating effect of warm water on the majority of people. We must therefore set aside all such arbitrary rules, and each person must decide for himself regarding the articles best adapted to his own peculiar digestive powers.

The food should be sufficient in quantity and thoroughly masticated, for if the stomach is overloaded it can not do its work properly. It is no doubt wise, when a person has command of his own time, to abstain from mental or physical exertion for a short period after eating. But how few will abstain from either, and, even if they do, they are apt to become morbidly careful, and, in their anxiety to obtain perfect health, render their own and the lives of those who come in contact with them insupportable.

Indigestion is often a symptom of some disease, such as an imperfect production of pepsin or hydrochloric acid by the gastric follicles: such cases may be relieved by the use of the missing constituents of the gastric juice as medicines. Regurgitation of bile or pancreatic juice from the duodenum into the stomach will also produce indigestion, by neutralizing the acid of the gastric juice. Cancer, and many other diseases, the consideration of which we have not the space to review, also seriously interfere with the digestive process.

There are peculiarities in the digestive apparatus of some animals which are of interest to the physiologist. An excellent example is afforded by ruminants, *Fig.* 64, which possess four stomachs, called the ingluvies, or moistening stomach, *b*, which

Fig. 64.



Stomachs of Ruminant.

How are the digestive powers of a person to be determined? Of what diseases is indigestion a symptom? How is deficiency of pepsin to be treated? How does regurgitation of bile act? Name the stomachs of the cow.

receives the food from the œsophagus, *a*; second, the honeycomb, or second moistening pouch, *c*, from which the food is sent to the mouth, to be again chewed as the cud, and returned to the third stomach, called the omasum, *d*, from which it passes into the fourth stomach, *e*, and finally escapes at the pylorus, *f*. In the porcupine there are also four stomachs, while in the kangaroo there are eight of these organs.

Fig. 65.

Stomachs of Kangaroo.

The nature of the food has a great influence on the character of the digestive apparatus, especially as regards its length. In the carnivora it is very short, being but little more than a straight tube. A complex elongated intestinal canal in such animals would be superfluous, for their food is so rich in nutritive material, and so easily digested, that only a part of the canal would be used.

In the herbivora, on the contrary, an enormous amount of food has to be digested, in order to obtain sufficient nutriment to satisfy the wants of the animal. Not only is the bulk very great, but the nutritious parts are difficult of extraction, and require a more complex apparatus than that needed for the solution of such concentrated food as flesh; consequently, the intestinal canal is elongated, and in those animals that require a large quantity of nutriment, on account of their size, as the Asiatic elephant, the colon alone reaches a length of more than twenty-six feet, while in those whose food contains a very small proportion of nutriment, as the Arabian dromedary, which feeds on dry stubble, it reaches the enormous length of forty-six feet.

In *Fig.* 66, page 62, the cæca of the common fowl are represented; *a* being the œsophagus; *b*, the crop, or insalivating pouch; *c*, the stomach; *d*, the gizzard, or masticating pouch; *e*, the liver; *f*, small intestine; *g*, the cæca; and *h*, the cloaca.

The digestive apparatus of birds, as well as of animals, is influenced by the nature of the food, the cassowary, which has a plentiful supply of highly nutritious food, having a colon one foot in length, and two cæca, each six inches in length, while

What is the influence of the food on the length of the digestive canal? What are the peculiarities of the intestines of the herbivora? What is the length of the intestine in the elephant and dromedary? Compare the length of the intestine in the cassowary and the ostrich. What parts compose the digestive tract of birds?

Fig. 66.

Digestive Tract of common Fowl.

the ostrich, whose food is scanty, and not very nutritious, has a colon forty-five feet in length, and two cæca, each two feet nine inches long.

We might mention many examples in the other kingdoms and orders of animal life which would illustrate the influence of food on the length and character of the digestive tract, but the instances furnished are as strong and convincing as any that could be presented; we therefore pass to the examination of the processes employed in the separation of the soluble nutritious elements of the digested food from those which are insoluble or effete, and consequently of no use in the human system.

LECTURE XIII.

CAPILLARY ATTRACTION AND ENDOSMOSIS.

Composition of Fæces.—Origin and Diurnal Amount of Fæces.—Intestinal Gases.—Capillary Attraction.—Examples and Explanation of Capillary Attraction.—Dialysis.—The Endosmometer.—Endosmosis.—Exosmosis.—Action of Gum in the Endosmometer.

Absorption of the digested food commences in the stomach, and continues throughout the intestinal canal to the anus, until all the nutritive matter is conveyed into the system, and nothing remains in the intestines but useless residue, to which the name of fæces is given.

Fæces are composed of, 1st. Cellulose, or the woody fibre of vegetables and grain, which, though it is digested by beavers and many insects, and is their chief article of food, is not acted on by the digestive juices of man and the great majority of animals; 2d. Starch granules, which have escaped the action both of the saliva and the pancreatic fluid; 3d. Shreds of muscular fibre; 4th. The coloring matter of the bile, which has been derived from the coloring matter of the blood, and contains a considerable amount of iron; 5th. Epithelium, from the intestinal mucous membrane, and the glands connected with the digestive apparatus.

What is the composition of fæces?

The diurnal amount of dried fæces is about one and one quarter ounces. The apparent quantity is much greater, but that is easily accounted for when we consider the large proportion of water they contain when freshly voided.

With the fæces certain gases pass from the intestine. They are, 1st. Nitrogen, derived from the air that was mixed with the food during mastication and swallowed; 2d. Carbonic acid, derived in part from the blood, and in part from the partial decomposition of the food during digestion; 3d. Sulphureted and phosphoreted hydrogen, also formed by the decomposition of food, or secreted from the blood. They give to the gaseous discharges of the intestine their disagreeable odor.

In order to study the phenomena of absorption in an intelligent manner, we must first examine into the nature of certain physical forces by means of which it is accomplished. The physiologists of olden times regarded the pyloric valve with peculiar interest, for they thought that it presided over this function, and determined what articles should be introduced into the system, and what should be ejected as fæces. By the light which modern science and patient, painstaking examination and experiment have thrown on this function, we now see clearly what the true nature of absorption is, and reason concerning it just as we would regarding any ordinary manufacturing process.

The force called into play during the act of absorption, both in plants and animals, is capillary attraction, by which is meant the power tubes of narrow calibre possess of raising a liquid above its proper level when they are placed in it.

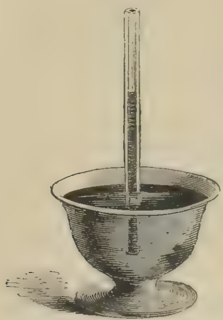
It may be illustrated by heating a piece of thermometer tube near its centre, and turning it while it is in the flame so that it may receive the heat equally on all sides. When it has attained a bright red heat it is drawn out, and a perfect tube finer than a hair is obtained, which, being touched to a drop of water, raises it to a considerable height.

The height to which a tube can raise a liquid depends on the diameter of its bore, as may be illustrated by placing in water tubes of diameters varying from half an inch to the finest that can be made, when it is found that the finer the tube the greater the height to which it can raise the liquid.

All liquids are not raised by tubes of glass, but some, such

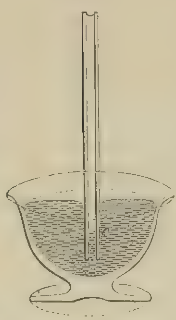
What is the diurnal amount of fæces? What are the intestinal gases? What is their origin? What was the old idea regarding the pyloric valve? What is capillary attraction? What determines the height to which a tube can raise a liquid? Are all liquids raised by tubes?

Fig. 67.



Elevation of a wetting Liquid.

Fig. 68.



Depression of a non-wetting Liquid.

as mercury, are depressed. The true cause of the phenomena of capillary movement seems to be electricity; for if the conditions of the liquid and tube are examined, they are found to present opposite electrical states when the liquid is raised, and similar electrical conditions when it is depressed. If the fluid rises we say that it is by virtue of the property it possesses of wetting the tube; and since different fluids possess this power to different degrees, it sometimes seems as though the tubes possessed an inherent power of selection, permitting a passage to some fluids and denying it to others.

The selecting power, as it is commonly called, can be controlled by very simple physical causes. For example, if we take a bundle of ordinary lamp-wick and moisten it with water, and then dip it into a mixture of oil and water, the latter will rise, but the oil will not. If we perform the experiment by first wetting the wick with oil, the oil will rise and the water will be left behind.

Though a capillary tube can be prepared in such a manner as to raise a specified liquid, it can not establish a continuous flow through its interior when it is broken off short of the point to which it raises the liquid. The fluid, under such circumstances, merely rises to the broken extremity of the tube, and remains stationary.

If we take measures to remove the liquid from the broken extremity as fast as it rises, either by means of a piece of blotting-paper, or by evaporation, combustion, or any other suitable method, the fluid in the tube will rise to take the place of that which is removed, and a current can so be established.

The statement made in the previous paragraph may also be applied to membranes, which may be regarded, since they are more or less porous, as consisting of an infinite number of exceedingly short capillary tubes, which extend from one surface of the membrane through its texture to the other surface.

How is capillary attraction explained? What is meant by the selecting power of tubes? Give some examples. Will liquids flow continuously through short capillary tubes? Under what circumstances can continuous currents be established in tubes? What is the composition of membranes?

When such membranes are formed into a sac or bag, which is filled with a liquid that can wet its pores, the fluid quickly permeates the membranous barrier; and if it is removed as fast as it reaches the opposite side, the receptacle will soon become empty.

This property is now applied in some manufacturing operations to the separation of fluids from each other, by placing them on the opposite sides of a membrane, and adjusting the conditions necessary to produce the desired result. It is described in chemical works as the method by dialysis. A very simple illustration of this action is to take a mixture of alcohol and water, place it in a bladder, and suspend it in a current of air. The water in the mixture quickly wets the bladder, passes through and is evaporated from the exterior surface of the membrane, while the alcohol, having little or no affinity for the membranous structure, remains in the bladder, and is finally so perfectly freed from water as to be almost absolute or pure.

The power membranes possess of causing certain liquids to move through their tissue is altogether independent of pressure, and will, as we shall hereafter see, go on without restriction against the greatest pressures we can call into action.

Fig. 69.

The Endosmometer.

The above fact is illustrated by the experiment represented in the adjoining figure. The apparatus is called an endosmometer, and consists of a small bladder filled with alcohol, and attached water-tight to a narrow tube two or three feet in length, and placed in a large vessel of pure water. The water, having a great affinity for the membrane, passes through it, but, as soon as it reaches the interior surface of the bladder, it is dissolved away by the alcohol; at the same time, the alcohol moves in the opposite direction, viz., to the exterior of the bladder, and is in its turn dissolved by the water on the outside; but as the water wets the bladder better than the alcohol, it passes through its texture more rapidly, and consequently there is an accumulation of liquid in the interior of

How do membranes act on liquids? Upon what condition does the movement depend? How is this principle employed in manufactures? How may alcohol be concentrated? Does pressure influence the action of membranes on liquids? Describe the endosmometer. How does the endosmometer act?

the bladder; this is at once relieved by the fluid rising in the tube, and finally reaching the upper extremity, where it forms large drops, and may be collected in considerable quantity as it falls. The tube may be lengthened to an indefinite extent, the liquid still rises in a perfectly unobstructed manner until the column is so high as either to cause the bladder to burst, or rupture the ligature that binds it to the tube.

It must not be supposed that the movement of the alcohol into the water, *endosmosis*, as it is called, will go on for an indefinite period, for it has a limit, which is reached as soon as the liquid in the interior and that on the exterior of the bladder are composed of equal proportions of alcohol and water; it then ceases, and can only be renewed by adding more alcohol to the contents of the bladder, or water to the liquid on its exterior.

If, instead of placing alcohol in the interior, we place it on the exterior of the bladder, and fill it with water, the movement still goes on, but it is in the outward direction; consequently, instead of there being an accumulation of liquid in the bladder, there is a loss; it becomes partially empty. This movement is called *exosmosis*, in contradistinction to that previously described.

Substituting a solution of gum for the alcohol, we find it acts in the same manner. When it is placed in the bladder, and the instrument is immersed in water, endosmosis is produced; and when the arrangement is changed as described in the last paragraph, there is exosmosis.

LECTURE XIV.

ABSORPTION.

Mechanism of Absorption in Plants.—Functions of the various Parts.—The ascending Sap.—The Force it exerts.—Descending Sap.—Description of a Villus.—Lacteals.—Receptaculum Chyli.—Thoracic Duct.—Stomach Absorption.— Villus or Intestinal Absorption.—Action of Mesenteric Glands.—Effect of Disease of Mesenteric Glands.

Understanding clearly the physical forces just described, we can intelligently pass to the study of absorption; and since plants afford us highly interesting illustrations of this function,

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Where does the liquid accumulate when the alcohol is in the bladder? How long will the endosmosis continue? Under what circumstances is exosmosis established? Can other fluids be substituted for the alcohol?

it will be to our advantage to describe first the mechanism and method of absorption in plants, and then apply the information we have gained to the examination of the same apparatus in animals.

Commencing at the root of a plant, we find that the terminal roots originate in small sacs or bags, called spongioles, which have a thin membranous wall; from the spongiole a fine ligneous tube passes along the root, trunk, and branch, to a twig, and finally terminates in a leaf, where it subdivides into capillary vessels called veins, which are distributed to the upper surface of the leaf. Turning to the under surface, a return system is formed, by which the sap that has ascended from the spongiole is conveyed to the roots.

On the under surface of the leaf a great number of open-mouthed cells or cavities, called stomata, are connected with the return system of veins; it is their province to present the sap, under the most favorable conditions, to the action of the ascending currents of air, which are rising through the leaves of the plant, and cause the evaporation of a portion of the water, and consequent concentration of the sap.

The fluid in the spongioles is a concentrated solution of gum-water. The exterior of the spongiole is in contact with moist soil, the water of which contains various salts and other solid materials, dissolved from the strata through which it has percolated. Through the wall of the spongiole the gum-water passes, and, at the same time, the water of the soil moves in the opposite direction; but, since the latter moves with greater rapidity than the former, there is an accumulation of fluid in the spongiole, and it rises in the tube, as in the experiment in endosmosis, described in a previous paragraph.

The spongiole, therefore, is the source of power which compels sap to rise to the highest twigs of the loftiest trees, and it seems almost incredible that so delicate a mechanism should produce such wonderful results.

The ascending sap is very dilute, containing a little gum and the salts which were absorbed in solution in water by the spongiole; it passes up the vessels of the plant to the upper surface of the leaf, where it is brought, under the influence of light, in contact with the carbonic acid of the air. Under these conditions, water and carbonic acid are decomposed, oxygen is set free, and gum formed. Ammonia and other substances

Describe the mechanism of absorption in plants. What are stomata? What is their function? Describe the action of the spongioles. What is the composition of ascending sap? How is it changed in the leaf?

are also acted on; but it will simplify our explanation if we disregard them, and merely trace the course of the gum. From the upper surface the sap turns to the under side of the leaf; the dilute solution which was formed on the upper surface is concentrated by the action of the stomata, and a moderately strong solution of gum-water formed, which, as it passes down the tree, is called the descending sap; it nourishes the tissues of the plant, and, finally reaching a spongiole, aids in introducing fresh materials.

The force with which sap rises in plants is uncontrollable, as may be demonstrated by cutting off a grape-vine near its root and attaching a pressure-gauge securely to the cut extremity. The sap will rise from the root into the cut trunk and gauge until a pressure of ten or twenty atmospheres is reached, and it would show a far greater force, but it is impossible to make joints which can bear the strain. The only practicable limit to the pressure the rising sap can be made to exhibit is the fragility of the apparatus employed, and there is no doubt but that it would take place against fifty atmospheres as easily as against five.

Passing from plants to man, we find that the villus of the intestine is the analogue of the spongiole of the plant; and just as the spongiole absorbs from the earth, water and nutriment, so the villus, and also the blood-vessels of the gastric mucous membrane, absorb from the digested food its nutritive parts, and introduce them into the system (p. 42, *Fig.* 57).

A villus is most readily described by commencing at the interior and passing outward; following this plan, we find in the interior the termination of a lacteal tube, which forms a species of elongated bulb; outside of this there is a layer of blood-ves-

Fig. 70.

Villus showing Termination of the Lacteal Tube.

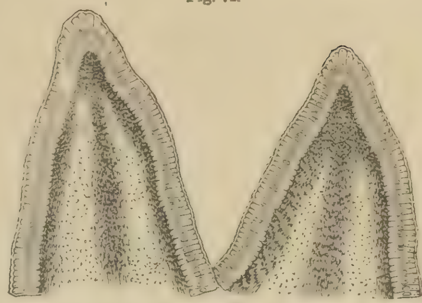
Fig. 71.

Villus showing Blood-vessels.

What is the composition of descending sap? How is it finally disposed of? How may the force of the ascending sap be demonstrated? How much pressure will it exert? What organ in man is analogous to the spongiole? Describe the parts which compose a villus.

sels and muscle-cells, covered by columnar or cylindroid epithelium, which comes in contact with the chyle formed in the intestinal canal during digestion.

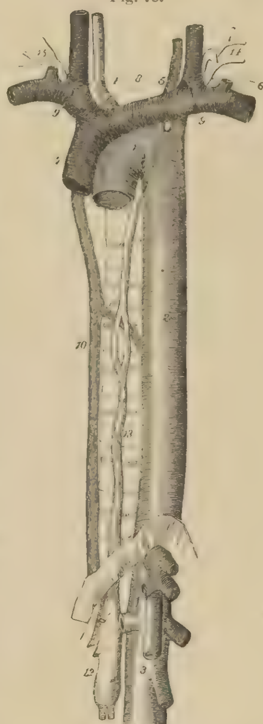
Fig. 72.



Villi showing External Cylindroid Epithelium.

From the villus the lacteal passes through one or more mesenteric glands, and, uniting with other lacteals, forms larger and larger trunks, which finally enter a long tube half an inch in diameter and four or five inches in length, called the *receptaculum chyli*, which lies on the lumbar vertebræ.

Fig. 73.



Thoracic Duct.

A delicate tube, called the *thoracic duct*, passes from the upper extremity of the receptaculum chyli, and, traversing the thoracic cavity, empties into the left subclavian vein at its junction with the internal jugular, as is shown in the figure, 1 being the arch of the aorta; 2, thoracic aorta; 3, abdominal aorta; 4, arteria innominata; 5, left carotid; 6, left subclavian; 7, vena cava descendens; 8, venæ innominatæ; 9, subclavian vein; 10, great vena azygos; 11, lesser vena azygos; 12, receptaculum chyli; 13, thoracic duct; 14, the curve of the thoracic duct; 15, the right lymphatic duct.

For convenience of description, the function of absorption may be studied under two divisions: 1st. Stomach absorption; 2d. Villus absorption. In the first the veins of the stomach take up by endosmosis the nutritive materials which have been converted into chyme by the action of the gastric juice; such bodies, therefore, as fibrin, albumen, casein, and gluten enter directly into the blood-vessels as soon as they are digested.

How is the fluid that has entered the villus disposed of? Where and what is the receptaculum chyli—the thoracic duct? What is the course of the thoracic duct? Into what does it empty? What are the divisions of absorption? Describe stomach absorption. What articles of food are absorbed in the stomach?

In villus absorption, on the contrary, after the chyle has reached the interior of the lacteal tube, it is obliged to pass through the mesenteric glands, which are connected with the lacteals. Before entering the glands the chyle is composed of albumen and fat, but after it has passed through them it contains fibrin and large nucleated cells, called chyle corpuscles.

Fig. 74.

Chyle Corpuscles.

These corpuscles are of great interest, for they are the mother cells from which blood discs are born. In children the mesenteric glands are often diseased, the peculiar substance called tubercle, which is formed in the lungs in consumption, being deposited in these glands in very young persons. Whenever this occurs, the function of the glands is seriously interfered with; chyle corpuscles and fibrin are not produced; the blood and muscles are not properly nourished, and the child is pale and emaciated; its strength grows less and less every day, until death supervenes.

Leaving the mesenteric glands, some of the lacteals enter the veins of the intestines, but the great majority pass to the receptaculum chyli, so that the oils and fats follow a very circuitous route before they finally enter the blood.

LECTURE XV.

BLOOD.

Properties of Sap.—Of Blood.—Variations in the Appearance of Blood.—Composition of Blood.—Influence of Sex and Climate on its Composition.—Function of Water.—Of Albumen.—Of Extractive.—Of Fats.—Of Salts.—Of Fibrin.—The Clot.—Action of Mesenteric and Lymphatic Glands.—Red Blood Discs.—White Discs.—Hœmatin.—Globulin.—Plasma.—Serum.

All plants and animals possess a circulating nutritive fluid or juice; in plants it is called sap; in animals, blood. The color of the nutritive fluid varies, being sometimes white, and oft-

What change is impressed on chyle during its passage through the mesenteric glands? What are chyle corpuscles? What is the effect of disease of the mesenteric glands? Do the lacteals empty into the receptaculum chyli? What is the nutritive juice of plants—of animals? What are the variations in color?

en colorless; but in animals it is generally either red or blue, according as it is arterial or venous. When first drawn from a free opening, blood is always perfectly fluid; but after it has stood for a time a portion turns solid, forming a mass called a clot, which floats in the fluid part, to which the name of serum is given. While yet in the arteries and veins, the blood retains its fluidity, and consists of minute red cells, which float in a tawny-colored liquid called plasma.

The total weight of blood in the system was determined by an extensive series of experiments on decapitated criminals to be equal to one eighth of the weight of the body. It is continually changing, since it is the channel through which the ingesta are introduced into the system. The nature and extent of the change may be realized when we reflect that the total weight of this fluid in the body, according to the results of the experiments spoken of above, is less than twenty pounds, and the annual amount of ingesta is more than three thousand pounds.

There are slight variations in the nature of the circulating juice in the different sexes, the blood of males being heavier than that of females. Climate also produces its influence, causing that of the inhabitants of tropical regions to be darker colored than that of persons living in cold countries. In all animals it possesses an odor peculiar to each species; by adding a little sulphuric acid to a sample of blood obtained from an unknown source, it gives out the peculiar odor of the animal from which it was obtained, enabling us to determine its origin.

The reaction of human blood is alkaline; and since it contains a considerable amount of nitrogenized substances, it is very prone to undergo decomposition, giving off a disagreeable putrid odor.

The substances which enter into the composition of blood are

Water	784	Plasma.
Albumen	70	
Extractive and fat	6.77	
Salts	6.03	
Fibrin	2.20	
Discs	131.00	
	1000.00	

What is the appearance of freshly-drawn blood? How does it change? What is the total weight of blood in the body? How was it determined? Is the composition of the blood fixed? What is the influence of sex on the composition of blood—of climate? How may the odor of blood of different animals be evolved? What is the reaction of blood? What is the composition of blood? What is plasma?

Water forms the basis of the fluid; it is subject to slight variations in quantity, depending on its use. If it has been recently introduced into the stomach, the proportion may rise considerably above the figures in the table; if it has not been taken for some time, the percentage will fall below the standard quantity.

The albumen is the representative of the nutritive group; out of it all the tissues of the body are formed to a greater or less extent; it is derived from the albumen, fibrin, gluten, and casein which were introduced into the stomach as food. The constitution of these substances is almost identical, at least as far as the number and character of atoms composing them is concerned. Their conversion into the albumen of the blood is therefore very simple, and is probably accomplished by merely rearranging their component atoms so that they are grouped in the same manner, and consequently out of substances which possess different physical properties and qualities one homogeneous material is formed.

The extractive is a term applied to certain substances contained in blood, and nearly all the fluids and tissues of the body. It appears to be formed of a number of organic materials, which give characteristic properties, such as a definite color or odor, to the substances they compose. The extractives have as yet been examined only to a very slight extent, and but little is known concerning them. The proportion in the solid ingredients of some of the fluids of the body is very large, and the study of this class of substances offers a more promising field of discovery to the physiologist than any other department of his science.

Fats are derived from the oily and fatty substances employed as food; they belong to and represent the respiratory class, and are used in the system to produce the heat which enables all animals to keep their temperature either above that of the medium in which they live, or at some fixed degree.

As has been already stated, the fats are in part turned into sugar in the liver; in this state they are probably more prone to undergo oxidation in the systemic and pulmonary blood-vessels. Those portions which are not converted into sugar are stored away in the cellular tissues of the body, and form the fat of the animal.

What is the function of water in the blood? How may the proportions vary? What does albumen represent? From what is it derived? What is the extractive? What is the function of fats? What is the action of the liver on fats?

The most important salts are chloride of sodium, phosphate of lime, and phosphate of soda. The common salt, or chloride of sodium, is, as we have seen, used to furnish the hydrochloric acid of the gastric juice, and the soda of the bile. When the absorption of the digestive material is completed, these bodies meet again in the general circulation, reunite, and form salt, which may be again decomposed to furnish another supply of acid and soda. A very small amount of salt can in this manner be caused to furnish an almost unlimited supply of digestive juices; and though man continually renews the salt in his system, there are many animals, such as the buffalo, which resort at a special season of the year to regions where salt deposits exist, and obtain a supply of that material which lasts for many months.

Phosphate of lime is employed to nourish the bones and teeth. In the early period of the life of an animal very large supplies of this substance are required, and we find that milk contains a considerable proportion of bone phosphate. The diurnal amount of this phosphate in the milk of the mother is greater than that introduced into her system each day in her food; under these circumstances, the milk phosphates are derived from the osseous tissues of the parent; consequently, during the nursing period, when the bones of the young are being consolidated, those of the mother steadily lose phosphate of lime, and the osseous tissues of the child are literally constructed out of those of the parent.

Phosphate of soda presents one peculiarity which is of great interest as regards the movement of carbonic acid gas in the body. If pure water is taken, it is found that at a given temperature and pressure it will absorb a definite volume of this gas; but if to the water phosphate of soda is added, it then takes up a far larger volume of gas than it dissolved when in the pure condition. The presence of phosphate of soda in the blood therefore enables it to dissolve and hold in solution all the carbonic acid evolved in the body.

Though the fibrin appears to be in such small proportion, it is one of the most important ingredients. It possesses the power of spontaneous coagulation, and may be obtained by whipping freshly-drawn blood with a bundle of twigs; under

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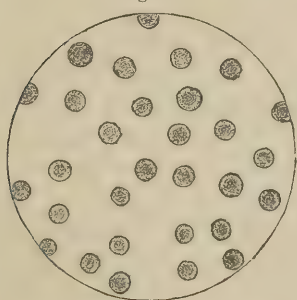
What are the salts in the blood? For what purpose is the chloride of sodium employed? How is the percentage of salt in the blood maintained? For what purpose is the phosphate of lime employed? How is the large proportion of phosphate of lime in the milk obtained? What property does the phosphate of soda impart to the blood? How may fibrin be obtained from blood?

these circumstances, the fibrin, as it coagulates, attaches itself to the twigs, and is obtained as a light yellow material in the form of a stringy mass.

The clot produced when blood coagulates is composed of the fibrin of the fluid, which, as it takes on the solid condition, forms a network of fibres in which the discs are entrapped. At first the clot appears to occupy the whole mass of the fluid, but, as soon as the fibrin is coagulated, it commences to contract, and the size of the clot steadily diminishes until it is quite small and hard. The contraction of the fibrin in the clot is the last living act of the blood.

Fibrin is produced in the system at the rate of sixty-two grains per hour, but the quantity in the blood is unchanged, since the muscles appropriate it as fast as it is formed. If chyle is examined after its passage through the mesenteric glands or lymph, after it has been subjected to the action of the lymphatic glands, they are both found to be very rich in fibrin, while albumen has disappeared; we therefore conclude that fibrin is produced out of albumen by glandular action.

Fig. 75.



Human Blood Discs 500 Diameters.

The discs are shaped like a coin, being circular and flat; they are about $\frac{1}{3200}$ of an inch in diameter, and $\frac{1}{12000}$ of an inch thick. The cell wall of the disc is composed of a substance called *globulin;* the fluid content is *hæmatin,* which contains a very large amount of iron, and is of a deep red color.

If freshly-drawn blue or venous blood is placed under a jar containing oxygen, it turns red, becoming arterial. This change is due to the discs absorbing oxygen, the hæmatin having an affinity for that gas, and yet not uniting with it, but merely dissolving it, to surrender it up again. The union of oxygen with hæmatin is so weak that we may readily separate them by placing the fluid under an air-pump jar, and exhausting, when the oxygen is immediately set free.

In addition to the red corpuscles or discs, there are large

Which constituents of blood form the clot? Describe its formation. What is the rate of production of fibrin in the body? What change does chyle undergo in passing through the mesenteric glands? What change do the lymphatic glands impress on lymph? Describe the discs. What is their diameter? Of what is their cell wall composed? What is the name of the fluid? What is the effect of oxygen on venous blood? Is the oxygen closely united with the hæmatin? How may it be separated?

spheroidal cells floating in the blood, which differ from the red discs not only in color, but also in their specific gravity; they move along in the current of the circulation in a tardy manner, seeming to cling to the walls of the capillaries and smaller blood-vessels.

The white discs contain a number of nuclei, while the red discs do not have any nucleus, though at times they appear, under the microscope, to be nucleated; but it is a deception produced by the figure of the disc, the surfaces of which are not perfectly flat, like those of a coin, but slightly curved, being sometimes concave and at others convex.

The red discs originate from the white discs, to which the name of mother cells or corpuscles is given; the method of production is by rupture, the white corpuscles bursting or their walls dissolving, and the nuclei, being set free, assume the red tint, and become full-grown red blood corpuscles. We may therefore say that the red discs are the nuclei of the white discs, and are set free when the mother cells are destroyed.

The white discs in their turn, originate from chyle corpuscles which were formed in the mesenteric glands. When these glands are diseased, as is frequently the case in young children, the muscular and other tissues of the body become soft, the blood loses its color, and the lips and skin no longer present the natural ruddy hue of health. These changes are all due to the fact that the diseased gland fails to produce chyle corpuscles with sufficient rapidity, and consequently the number of red discs in the body is greatly reduced.

As we view the blood under the microscope, we find that it consists of separate discs floating in a fluid; to this liquid the name of plasma is given. It contains all the other constituents of the blood, and differs from serum in that the latter fluid has lost its fibrin during the formation of the clot.

It has been estimated that twenty millions of red blood discs are destroyed in each pulsation of the heart, and there is every reason for believing that the estimate is correct. On this basis, a man, in the course of eighty years, has created and destroyed in his system such a vast number of millions of millions of these organisms, that if we were to place them side by side so as to touch each other, they would form a line long enough to go around the earth more than ten thousand times.

Describe the white discs. What is their relation to the red discs? What is the origin of the white discs? Why are the red discs reduced in number in disease of the mesenteric glands? What is the difference between plasma and serum? How many discs are destroyed by each pulsation of the heart?

Astronomy has its wonders, and dismays us with distances which the mind of man can not grasp, telling us that though light moves with a velocity of thousands of miles in a second, there are stars so far distant that their light does not reach the earth for years after it is emitted by the star. Physiology also has its marvels; and though the number of blood discs produced in the system is almost incredible, it falls into insignificance when we compare it with the total number of cells produced in the body during a lifetime.

LECTURE XVI.

THE BLOOD-VESSELS.

The Divisions of Blood-vessels.—Their Composition and Character.—Order of Development of the Blood System.—The Heart described.—The Pericardium and Endocardium.—Muscular Tissue of the Heart.—Its Cavities, their relative Position.—Rate of Pulsation.—Valves.—Their Function.—Valvular Sounds.—Diseases of the Valves.

From the consideration of the character and properties of the blood, we now pass to the study of the vessels in which it circulates.

The blood-vessels are divided into three classes, viz., arteries, veins, and capillaries. The arteries have thick walls, and are empty after death, their coats being so elastic as to enable them to retain the circular tube-like form. Owing to this peculiarity, it was formerly supposed that they conveyed air to all parts of the body. The veins, on the contrary, have such thin walls that they collapse when empty; they are also provided with valves, which open toward the heart. The walls of both arteries and veins are composed of three coats, an exterior layer of condensed cellular tissue, and an interior thin smooth membrane. Between these there is a layer of elastic fibrous tissue, which contains involuntary muscle cells. Some physiologists speak of it as the muscular coat, while others call it the elastic coat.

When the arteries in the living body are cut, either by intention or accident, the blood flows from them in a strong intermitting current, the impulses corresponding to the pulsations

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What are the three classes of blood-vessels? What is the difference in appearance between the arteries and veins after death? To what is this due? What are the three coats of blood-vessels? What is the character of the flow of blood from veins and arteries when wounded?

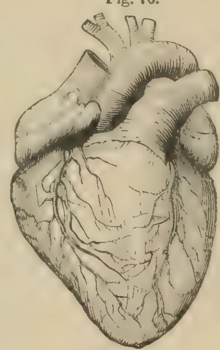
of the heart. The only way to stop the flow from the large arteries is to tie them with a stout silken string called a ligature. When a vein is cut the flow of blood is dark blue, that from the artery being crimson or arterial. The nature of the flow also is different, being continuous, and not possessing the jerking character which marks the flow of blood from an artery.

The large veins and arteries continue to subdivide until the branches are so small as to escape ordinary vision. To these minute vessels the name of capillaries is given; they are about $\frac{1}{3000}$ of an inch in diameter, and constitute the channel of communication between the arteries and veins.

If we watch the development of the blood system in the egg of a frog, or in any suitable embryo, we find that the blood first appears; after that, the capillaries; then the larger blood-vessels; and, finally, the largest blood-vessel undergoes a dilatation in one part, the walls in this region becoming thickened, until a perfect heart is formed, the object of which is to regulate the flow of fluid through the vessels.

The heart differs in its character in different creatures: in some it contains a single chamber; in others, two; in others, three; but in all the animals of the class mammalia it contains four cavities.

Fig. 76.



The Heart.

In shape the heart resembles a cone, being four or five inches in length, and three or four in diameter at its base or largest part. The size of the heart of any individual is said to be equal to the size of the closed fist, but this estimate is of course merely approximate, and liable to very great error. It lies on its side in the thoracic cavity, across the median line, with the apex pointing downward and to the left, the base being uppermost, and on the right side of the sternum or breast-bone.

The heart is covered exteriorly by a stout fibro-serous membrane called the pericardium, which closely resembles the serous or synovial membrane of joints; and when we remember the ligaments which form the joints, and the fibrous nature of

How is the flow to be stopped? What are the capillaries? What is their diameter? What is the order of the development of the blood system? How does the heart differ in different animals? What is its shape? What is its size? What is its position? On which side is the apex? By what is the heart covered? What is the nature of the pericardium?

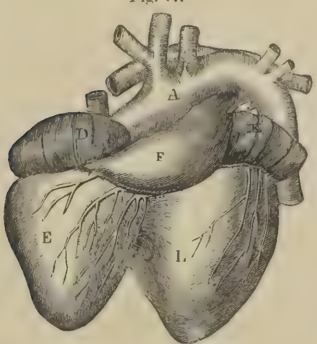
the pericardium, it is not at all surprising that rheumatism, a disease almost peculiar to joints, should often attack the heart, the constitution of which so closely resembles that of a joint.

The interior of the heart is lined by a serous membrane, the continuation of which also forms the inner layer or coat of the blood-vessels; it is called the endocardium.

The middle layer of the heart is composed of striated muscular tissue, arranged in bands, which are very prominent in its interior, crossing each other in all directions. In man the cavities are arranged in such a manner as to form two distinct hearts, each of which is composed of two cavities, one at the base, the other at the apex. The cavity at the base is called the ventricle; it is conical in form.

To the division of the heart which lies on the right side of that organ the name of the right heart is given; it receives the blue venous blood from the great veins of the body, and propels it to the lungs to be arterialized; it is therefore called by many authors the pulmonic heart. The left division is known as the left heart; and since it receives the crimson arterial blood from the lungs, and drives it through the great arteries of the system, it is called the systemic heart.

Fig. 77.



Heart of the Dugong.

In the dugong, the right or pulmonic heart is separated from the left or systemic heart, as is illustrated in the figure. A is the aorta; D, the right auricle; E, the right ventricle; F, the pulmonary artery; K, the left auricle; and L, the left ventricle.

The two divisions of the heart are arranged so that the auricles lie side by side, and form the base of the organ, while the ventricles are in a similar position at the apex. Since the auricles receive the blood sent to the organ, and empty it into the ventricles, acting as mere assistants to them, they are not required to exert any very great force; consequently their walls are very thin, being but little more than one eighth of an inch in thickness.

The ventricles, on the contrary, and especially the left, force

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Why is the heart liable to rheumatism? What is the endocardium? What tissue composes the middle layer of the wall of the heart? Name the cavities of the heart. What names are given to the right side of the heart? What to the left? What is the relative position of the auricles and ventricles? What is the duty of the auricles? How thick are their walls?

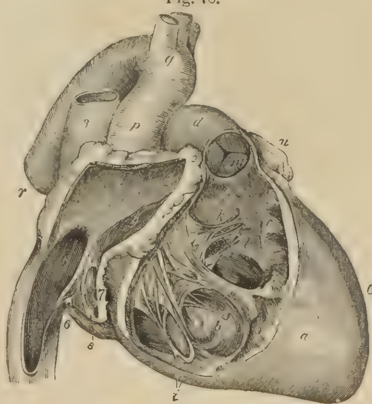
the blood into the arteries, and deliver it to the capillaries; their walls, therefore, are more substantial, that of the left ventricle being often three quarters of an inch thick.

It is estimated that the left ventricle contracts with a force equal to 13 lbs., the pressure of the blood in the aorta, or great systemic artery which conveys the fluid to the other arteries, being 4 lbs. 3 oz.

The number of pulsations in a minute varies with the age of the individual, being 130 to 140 at birth, 80 to 85 during childhood, 70 to 75 during adult life, and 50 to 65 in old age. It is also more frequent in females than in males. If we make due allowance for these variations, and estimate the amount of blood discharged by the ventricle into the aorta at three ounces, we find that at the age of eighty years the heart of a man has moved a mass of blood sufficiently large to build a column fifty feet square at the base, and twelve hundred feet high.

The auricles and ventricles are provided with valves which compel the blood to flow in a definite course—that is, from the auricle into the ventricle in each division. We may study them to advantage in their proper order. The first valve lies in the right or pulmonic heart, between the auricle and ventricle; it is composed of three divisions, which close the opening between the auricle and ventricle perfectly when they come in contact with each other. This is called the tricuspid, or three-lipped valve.

Fig. 78.



Right Side of the Heart.

The second valve closes the opening between the right ventricle and the pulmonary artery which conveys the blood from the heart to the lungs to be arterialized; it is composed of three half-moon-shaped divisions, which meet and touch when the valve is shut.

In the adjoining figure, from Wilson's anatomy, 1 is the right auricle; 2, its appendix; 3, vena cava descendens; 4, vena cava ascendens; 5, fossa ovalis; 6, Eu-

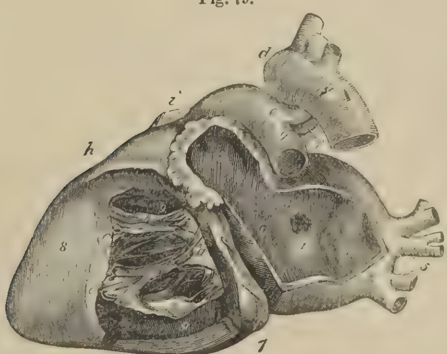
Which cavity of the heart has the thickest walls? What is the force exerted by the left ventricle? What is the pressure of the blood in the aorta? What is the rate of pulsation at birth—childhood—adult life—old age? What is the volume of blood moved by the heart in a lifetime? What is the direction the valves force the blood to follow? Describe the first valve, its name, composition, position; the second valve, name, composition, position.

stachian valve; 7, mouth of coronary vein; 8, coronary valve; 9, auriculo-ventricular opening; *a*, right ventricle; *b*, *c*, cavity of ventricle; *d*, pulmonary artery; *e*, *f*, tricuspid valve; *g*, the long columna carnea; *h*, the long moderator band; *i*, columnæ carneæ of the right curtain; *k*, *l*, tendons; *m*, valve of pulmonary artery, or semilunar valve; *n*, apex of appendix; *o*, left ventricle; *p*, the ascending aorta; *q*, its arch; *r*, descending aorta.

The function of the tricuspid valve is to prevent the blood flowing backward into the auricle after it has been forced into the ventricle, while the auricle is expanding and the ventricle contracting. The semilunar valves in the same manner close the opening into the pulmonary artery, and prevent the blood returning while the ventricle is expanding.

In the systemic heart, the valve between the auricle and ventricle is composed of two folds or divisions, and from its fancied resemblance to a bishop's mitre is called the mitral valve; it prevents the passage of the blood back into the auricle during the contraction of the left ventricle.

Fig. 79.



Left Side of the Heart.

The aorta, or artery given off from the left auricle, is closed by a valve similar to that found at the mouth of the pulmonary artery; it is called the semilunar, or fourth valve.

The figure represents the left side of the heart; 1 is the interior of the left auricle; 2, cavity of the appendix; 3, mouths of right pulmonary veins; 4, sinus into which left pulmonary veins open; 5, left pulmonary veins; 6, auriculo-ventricular opening; 7, coronary vein; 8, left ventricle; 9, cavity of ventricle; *a*, mitral valve; *b*, columnæ carnæ; *c*, columnæ carnæ of inner surface; *d*, arch of aorta; *e*, pulmonary artery; *f*, ductus arteriosus; *g*, left pulmonary artery; *h*, right ventricle; *i*, point of right appendix.

In the following figure, which represents the heart cut across

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What is the function of the tricuspid and right semilunar valves? Describe the third valve, its name, composition, position; the fourth valve. What are the duties of the mitral and left semilunar valves?

its base to show the valves, *t*, *t*, *t* is the tricuspid valve; *m*, *m*, the mitral; *e*, *f*, the semilunar valves of the aorta and pulmonary artery.

Fig. 80.

Valves of the Heart.

The two sets of semilunar valves have their margins perfectly free, and close the openings into the aorta and pulmonary artery by their contact. But the case is different with the mitral and tricuspid valves; their margins are attached by small tendons to muscles which arise from the walls of the ventricles, and which aid in working these valves in a proper manner. These muscles and tendons of the valve are beautifully shown in the heart of a sheep, as well as the relative thickness of the auricles and ventricles, and the muscular bands in the latter.

During its action the heart emits peculiar sounds, which are not produced, as was formerly thought, by the contraction of its muscular fibres, but are caused by the passage of the blood through the valves, and their sudden closure.

By the character of these sounds we may with ease recognize the contractions of the auricles and ventricles. The auricles at the base contract at the same moment, as is readily proved by vivisections on animals; the sound produced is represented by the syllable *lubb*. This is followed by the contraction of the ventricles, which also move together, and produce a sound represented by the syllable *tup*, shorter, quicker, and sharper than that produced by the auricles.

The first sound is caused by the passage of the blood through the mitral and tricuspid valves, and terminates by their sudden closure. The second sound is produced by the blood flowing through the semilunar valves of the aorta and pulmonary artery, and ends with their sudden closure, by the fluid forcing the valves back as the ventricles begin to expand, just as the valves of a forcing-pump act under similar circumstances.

In disease of the valves these sounds are changed, the modification being generally due either to the formation of a deposit on the valve, and its consequent thickening and roughening, thus obstructing the passage of the fluid from the auricle into the ventricle, or to its failure to close the opening between the

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What valves have free margins? What organs are attached to the mitral and tricuspid valves? What is their function? What is the nature of the sound produced by the auricles—by the ventricles? How are they produced? How are the sounds modified by disease? To what are the modifications due?

two cavities, permitting the blood to pass backward through the opening into the auricle.

When these abnormal conditions exist, the character of the sounds is changed, and a buzz or murmur accompanies the first long sound or the second short sound. The valves are often both rough and deficient; in such a case the murmur is heard with both sounds.

Not only can the experienced physician determine that the valves are diseased, but he can also state, with almost absolute accuracy, in which valve the disease exists. This is accomplished in part by finding where the murmurs are most intense, and by noticing other phenomena, such as the pulsation of the veins.

LECTURE XVII.

THE BLOOD-VESSELS—*Continued.*

Pulmonary and Systemic Blood-vessels.—Course of the Pulmonary Vessels.—The Aorta.—Its Divisions.—Its Termination.—The Cardiac Artery.—Arteria Innominata.—Common Carotid.—Subclavian.—Arteries of the Upper Extremity.—The Intercostal Arteries.—The Phrenic.—Cœliac Axis.—Superior Mesenteric.—Other Abdominal Arteries.

From the study of the heart we pass to the examination of the blood-vessels. They are divided into two classes: 1st. Those connected with the circulation of the blood in the lungs, called pulmonary vessels; and, 2d. Those engaged in the conveyance of nutritive material to the various tissues of the body, to which the name of systemic vessels has been given.

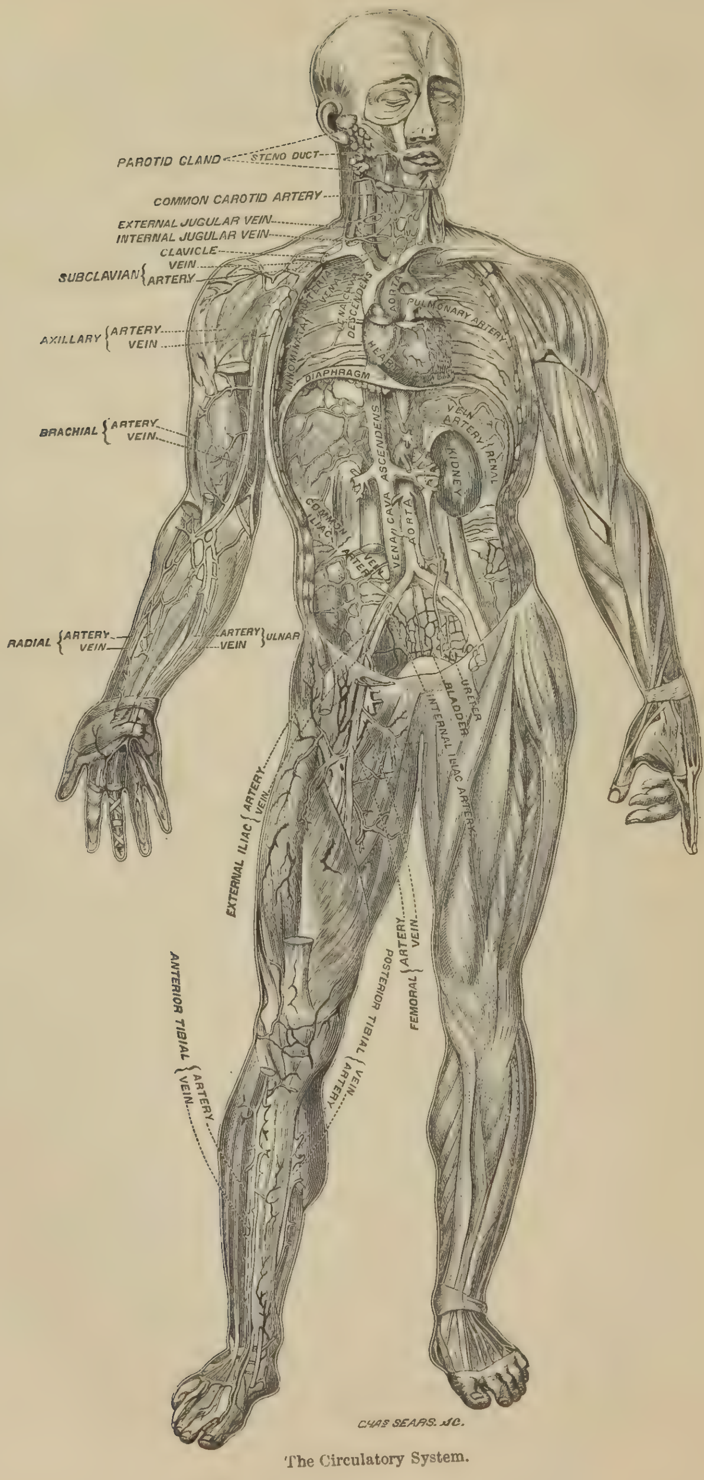
The pulmonary vessels consist of the pulmonary artery, which takes its origin from, and opens into, the right ventricle; it divides almost immediately into the right and left pulmonary arteries, one of which passes to the right, the other to the left lung, conveying the blue venous blood to those organs to be arterialized.

The right pulmonary artery enters the right lung at its root, and divides immediately into two branches, the upper division giving a branch to the middle lobe. The left pulmonary artery enters the left lung, and divides into two branches, which convey the blood into the two lobes of which it is composed.

Each of the large divisions of the pulmonary artery continue

Into what two classes are the blood-vessels divided? Name the vessels of the pulmonary system. Describe their course.

Fig. 81.



The Circulatory System.

to subdivide in the tissue of the lungs, until they finally terminate in capillary vessels, which are about $\frac{1}{3000}$ of an inch in diameter, enabling the discs, which are $\frac{1}{3200}$ of an inch in diameter, to pass through them with ease. The capillaries form an intricate network on the walls of the air-cells of which the lungs are composed; they then unite and originate larger vessels, which have the composition and structure of veins, and ultimately form four pulmonary veins, which pass from the lungs to the heart, and enter the left auricle at the base of the organ.

The systemic vessels are more difficult of description than the pulmonary, since they are more numerous and intricate.

The great artery which receives the blood from the left ventricle is called the aorta; it is about one inch in diameter, and is curved, forming an arch. The first part of the vessel passes upward, and is called the ascending aorta; the second curves and passes backward to the left side of the vertebral column: it is called the arch; while the third portion passes downward, lying partly on the left side and partly on the vertebral column: it is called the descending aorta.

The first part of the descending aorta lies in the thoracic cavity; it is consequently known as the thoracic aorta. It then passes through an opening in the diaphragm, or muscle which separates the two great cavities of the trunk, into the abdominal cavity, where it is called the abdominal aorta. In the lower part of this cavity it divides into two branches, the right and left iliac arteries, which supply the lower extremities with blood.

The branches of the aorta may be studied under the following divisions: 1st. Those of the ascending portion; 2d. Those of the arch; 3d. Those of the thoracic; and, 4th. Those of the abdominal portion.

The branch of the ascending aorta is the cardiac artery: it is given off close to the heart, so that its mouth is closed by the semilunar valves of the aorta when they open to give the blood passage into that vessel.

The branches of the arch are, 1st. The arteria innominata, which is about one and one half to two inches in length; 2d. The left common carotid; and, 3d. The left subclavian. On

Where are the pulmonary capillaries? How many pulmonary veins are there? What is the name of the great systemic artery? What is its diameter? What is its shape? Into what portions is it divided? What are the divisions of the descending aorta? How does it terminate? What is the first branch of the aorta? What are the branches of the arch? Describe the arteria innominata.

the right side the common carotid and subclavian are formed by the bifurcation of the arteria innominata.

From their origin the common carotids and subclavians on both sides pursue a similar course. We shall therefore describe the course of the vessels of the right side.

Fig. 82.

Carotid Arteries.

The common carotid, *a*, passes obliquely up the neck toward the angle of the lower jaw, where it reaches a position about opposite the Adam's apple; it divides into two branches, the external and internal carotids. The external carotid, *b*, passes up on the outside of the skull, giving off a number of branches, which convey blood to the scalp and other tissues of that region; the most important of these are the occipital, *o*, which passes to the back of the head; the maxillary and temporal, *y*, *g*, passing to the temples and the side of the head. The internal carotid, *c*, passes toward the apex of the petrous part of the temporal bone, where it enters the cranial cavity through a canal in that bone.

In man, the canal which contains the internal carotid is curved, so that the force of the pulsation of the ventricle is lessened by compelling the blood to follow a curved course. In many of the herbivora, in whom the head is kept for a long period in a dependent position while feeding, the carotid splits up into a number of small branches as it passes into the skull, producing a similar result in a more perfect manner.

After entering the cranial cavity the internal carotids unite, and form a series of communicating vessels at the base of the brain, called the circle of Willis, from which that organ is supplied with blood. The object of this free communication of the carotids from both sides is to produce an equality in pressure of blood on all parts of the brain, and also a free and equal supply in case either carotid should be injured.

Describe the course of the common carotid. What are its branches? Describe the external carotid, its course and branches; the internal carotid, its course. What are the peculiarities in the course of this artery in man and animals? Describe the circle of Willis.

The subclavian passes outward to the upper extremity, to supply it with blood. In the middle of its course it lies on the first rib, and under the clavicle; hence the name subclavian: it gives off a number of branches, which supply the muscles about the shoulder; one of these, called the mammary, passes down the front of the thorax, and communicates with an artery given off by the external iliac in the groin.

Reaching the armpit, the subclavian becomes the axillary until it gains the inner edge of the biceps muscle, when it is called the brachial; it follows the inner edge of the biceps down the arm to the elbow, where it bifurcates, sometimes above, but usually below that joint, into the ulnar and radial arteries.

The ulnar artery, as its name indicates, lies on the ulnar bone in its course down the fore-arm, while the radial lies on the radius. A third artery, called the interosseous, a branch of the ulnar artery, also passes down the fore-arm, lying between the two bones and on the interosseous ligament.

From the wrist the radial passes around the metacarpal bone of the thumb into the palm of the hand, lying on the metacarpal bones of the fingers, and uniting with the ulnar artery so as to form the palmar arch, from which the branches are given off to the fingers, called the digital arteries, which run along the outer and inner border of each finger.

Owing to the free communication of the ulnar and radial arteries in the palm of the hand, wounds of either of these vessels, or of the palmar arch, are apt to cause a considerable loss of blood; and it is necessary always to tie both ends of the cut artery, or, if there is difficulty in finding them, to tie the brachial high up in the arm.

In wounds of other arteries it is sufficient to tie the end of the artery nearest to the heart, as there is but very little chance of a flow of blood from the other extremity; but in the case of the ulnar and radial, the free communication through the palmar arch renders the precaution of tying both ends absolutely necessary.

The branches of the thoracic aorta are the intercostals, one to each rib. They run in a groove on the under and inner edge of the rib, so that they are protected from violence, and

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What is the course of the subclavian? What are its branches? Where does it become axillary? Describe the brachial. What are the terminal branches of the brachial? Describe the ulnar, radial, interosseous arteries. How is the palmar arch formed? Where is it? What are its branches? What is the peculiarity of wounds of the arteries of the fore-arm? What are the branches of the thoracic aorta? How are they protected?

can only be wounded by a knife, the edge of which is turned upward, and the blow struck so that the point of the knife passes upward, and not downward, as is usually the case when a person is stabbed in this region.

The first branch given off by the abdominal aorta is the phrenic. It takes its origin from the great arterial trunk, just as it is passing through the diaphragm, and, entering the tissue of that muscle, supplies it with blood.

The second branch of the aorta is called the cœliac axis. It is not more than half an inch in length, and divides into the gastric, splenic, and hepatic, each of which supplies the organ whose name it bears. The splenic and hepatic, in addition to supplying the spleen and liver, also give off branches to the stomach and pancreas.

Fig. 83.

Superior Mesenteric Artery.

The third great branch of the aorta is the superior mesenteric. It conveys blood to all the small intestines, and to the large intestine, with the exception of the descending colon, sigmoid flexure, and rectum.

The remaining branches of the aorta are the renals, of which there are two, one on each side: they pass to the kidneys; the inferior mesenteric, which passes to those parts of the large intestine not supplied by the superior mesenteric; the spermatic, which pass to the testicles; and the lumbar branches, which are analogous to the intercostals of the thoracic cavity: they run around the abdominal walls, and supply the muscles which form them.

What is the first branch of the abdominal aorta? Where is it given off? What does it supply? Describe the cœlic axis. What are its branches? What do they supply? What is the third branch? What does it supply? What are the remaining branches? What do they supply?

LECTURE XVIII.

THE BLOOD-VESSELS—*Continued.*

Common Iliac Arteries.—Internal Iliacs.—External Iliacs.—Arteries of the Lower Extremities.—Veins of the Head.—Of the Upper Extremity.—The great Veins of the Chest.—Veins of the Lower Extremities.—Portal Vein.—The Course of the Blood.

We have already seen that the aorta terminates below in the common iliac arteries, which pass to the right and left lower extremities. The branches of both of the common iliacs are the same on each side; we shall therefore only describe those of the right side.

The right common iliac passes to the brim of the pelvic cavity. It is about three inches in length, and divides into the internal and external iliac arteries; the former passes downward into the cavity of the pelvis, and supplies the organs it contains with blood. Some of its branches pass out through openings in the walls of the cavity, and supply the muscles about the buttocks and hips: its terminal branch, the pubic, supplies the genital organs.

The external iliac lies on the brim of the pelvis, and passes out of the abdominal cavity to the thigh. As it lies on the pubic bone, it gives off two branches, one of which is called the epigastric, which passes up the anterior wall of the abdominal cavity, and communicates with the mammary, a branch of the subclavian, so that when the external iliac is tied, blood can reach the lower extremity through this circuitous channel.

Reaching the thigh, the external iliac becomes the femoral, which gives off in its upper part a large branch called the profunda, that passes backward, and supplies the muscles on the back of the thigh with blood. In the upper third of the thigh the femoral is superficial, and all necessary operations are usually performed on it in this part. In the middle third it is deeper, and gradually passes to the back part of the thigh. In the lower third of the thigh the femoral becomes the popliteal

What are the divisions of the iliac arteries? What is the course of the internal iliac? What does it supply? What is the course of the external iliac? What are the divisions of the femoral artery? With what artery does the epigastric communicate? In what artery does the femoral terminate?

artery, which lies on the smooth surface of the posterior lower part of the femur. Opposite the head of the tibia the popliteal divides into the anterior and posterior tibial, the first passing down the leg in front of, and the second behind the interosseous ligament. In the foot, the arteries of the leg form the plantar arch, similar to the palmar, which gives off digital branches to the toes.

The veins commence in the capillaries in which the arteries terminate. In the brain the venous blood flows into large cavities formed by the membranes of that organ, and called sinuses; from these it is finally conveyed to the internal jugular veins, and carried by them down the neck to the shoulder, and delivered into the venæ innominatæ. The blood from the outside of the head is brought to the same point by the external jugular vein.

The veins of the upper extremity commence in the digitals which form the deep ulnar and radial. These unite at the elbow, and, receiving some of the superficial vessels of the fore-arm, form the brachial, which, passing up the arm to the armpit, becomes axillary, then subclavian, and finally unites with the internal jugular to form the vena innominata.

The right and left venæ innominatæ, uniting, form the vena cava descendens, which conveys the blood to the right auricle.

In the lower extremities the veins of the foot form the tibials, which, uniting at the back of the knee-joint, become popliteal, and then femoral, external iliac, common iliac, and finally vena cava ascendens, which empties the venous blood into the right auricle.

In addition to the veins we have mentioned, there are great numbers of small superficial vessels, but they all empty sooner or later into one of the large veins of the extremities or trunk. In the upper extremity there is a superficial vein, called the cephalic, which passes up the arm, conveying blood from some of the superficial vessels of the fore-arm to the subclavian. In the lower extremity there is a similar vessel, which commences at the large toe, and is called the saphenous vein: it carries blood from the superficial vessels of the lower extremity to the upper part of the femoral, into which it enters.

In the abdominal cavity the renals are the only veins of the

What are the arteries of the leg—of the foot? What is the origin of the veins? What are the veins of the head—of the upper extremity? What veins form the vena innominata—the vena cava descendens? Name the veins of the lower extremity. What veins form the vena cava ascendens? Describe the superficial veins. Describe the veins of the abdominal organs.

large organs, except the hepatic, that empty directly into the vena cava ascendens.

The veins from all the other viscera, viz., the stomach, spleen, pancreas, large and small intestines, unite together to form a short trunk of large diameter, called the portal, which enters the liver and there subdivides, causing the blood from the capillaries of all the abdominal organs except the kidneys to pass through a second system of capillaries in the liver; these, coalescing, form the hepatic, or vein of the liver, which empties the blood into the vena cava ascendens. The portal circulation of the liver is copied to a certain extent in the kidney, but we shall defer the description of the renal circulation until we take up the study of the kidneys.

From the anatomy of the circulatory system, we pass to the examination of the course the blood follows in its passage through the different parts of that apparatus.

The great discovery of the course of the circulation of the blood was made about two hundred years ago by Harvey. He founded his doctrine on the fact that the valves of the veins will only allow the fluid contained in those vessels to flow in one direction, viz., toward the heart; and the valves in the heart also impress upon the blood a definite movement, from the right auricle through the tricuspid to the right ventricle; then through the semilunar valves and pulmonary artery to the lungs; back by the pulmonary veins to the left auricle and ventricle; then through the aorta to the systemic capillaries, and back by the systemic veins to the heart, thus forming a figure 8, the meeting of the two circles being in the heart.

The discovery of Harvey was a grand step in the advancement of physiology and medicine, but it supposed that these movements were all caused by the contraction of the heart.

Direct experiment has shown that the force exerted by that organ is not sufficient to propel the blood through the capillaries; and we find, in attempting to inject these minute vessels, that a far greater force than that exerted by the heart is required to drive the most subtle injections into them; and they suffer so severely, that even in the most successful injection many capillaries are ruptured.

In the explanation of the portal circulation of the liver, Har-

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What is the portal vein? What is the portal circulation? What was the ancient idea regarding the arteries? What is the true course of the circulation? Who was the discoverer? When did he live? On what facts did Harvey found his doctrine? Is the force exerted by the contraction great enough to drive the blood through the capillaries into the veins?

vey's doctrine is altogether unsatisfactory; and if we consider the cases of monsters born without hearts, or, rejecting all other facts, reflect for a moment on the order in which the circulatory apparatus is developed, the heart being the last member of the system to appear, we find that though Harvey has taught us the course through which the blood flows, he does not satisfactorily explain the causes of its movement.

LECTURE XIX.

CIRCULATION OF THE BLOOD.

Harvey's and Draper's Theories.—Affinity of Liquids for Tubes.—Principle of Venturi.—Causes of the Circulation in Systemic and Pulmonary Vessels differ.—Perfection of Draper's Theory.—Course of various Articles to different Parts of the Body.

A RATIONAL and satisfactory exposition of the causes of the circulation was first given by Professor J. W. Draper, and, after many years of opposition from various physiologists, has been finally accepted as the true explanation of the movement of the blood.

Draper's theory places the force which causes the blood to circulate in the capillary vessels, and shows that the true cause of the movement is capillary attraction. The arguments by which this doctrine is supported are as follows:

1st. The heart does not exert sufficient force to drive the blood through the capillaries and veins; 2d. The portal circulation is carried on without a heart; 3d. The order of development of the circulatory system, and the existence of acardiac monsters, shows that the blood can circulate independently of a heart.

In the vegetable world, we find that plants have a circulating juice or sap which is moved without the agency of a heart. In these organisms, the circulating fluid is forced to an altitude which is sometimes to be measured by hundreds of feet, and is therefore propelled against a resisting pressure, compared with which the resistance to the movement of the blood in man falls into insignificance.

In plants the circulation commences in the fine capillary vessels in the roots, and terminates in fine capillaries in the leaves.

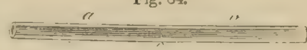
Where does Harvey's doctrine fail? What is Draper's theory of the circulation? How is the sap circulated in plants?

No heart is employed. The force generated by capillary attraction and endosmosis answers all the requirements; why, therefore, may not capillary attraction be the cause of the movement of the blood in animals, as well as of sap in plants?

In order to explain in a satisfactory manner the movement of the blood in the vessels containing it, we must first devote a brief space to the examination of certain physical phenomena upon which the circulation depends.

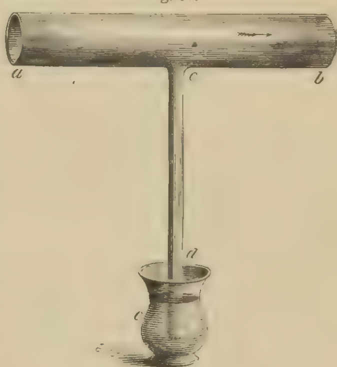
If there are two liquids in the tube *a v*, and the liquid *a* has a strong affinity for its walls, but loses it as soon as it reaches the point *c*, it is evident that there will be a flow from *a* through *c* to *v*, and the movement will continue until *a* is exhausted.

Fig. 84.



Motion in a Capillary Tube.

Fig. 85.



Principle of Venturi.

The principle of Venturi also has its influence in producing the circulation. If a current of fluid is flowing through the tube *a b*, and a smaller tube, *c d*, empties into it, a movement from the smaller into the larger tube will be established.

Applying these and other physical phenomena, of which we have spoken, to the explanation of the systemic circulation, we find that it is the function of the heart to keep the arteries filled with blood, that there may always be a free supply of fluid delivered to the capillaries. As it enters the capillary vessels the blood is arterial, the discs being laden with oxygen. The tissues through which the capillaries pass are composed of carbon, which, at certain times and in certain allotropic conditions, has an intense affinity for oxygen. The discs containing the oxygen consequently move forward to deliver it to the atoms of carbon which attract them.

As soon as the oxygen has been surrendered to the carbon, and carbonic acid formed, the blood no longer has any affinity for the walls of the capillary tubes, and the conditions that then exist are similar to those afforded in the case of the experiment with the liquids *a v*, and the tube *c*.

As fast, therefore, as the arterial blood becomes venous, and

If a liquid has an affinity for the walls of a tube, and gradually loses it, what is the result? What is the principle of Venturi? What is the duty of the heart? What is the action in the capillaries?

loses its affinity for the walls of the capillaries, it is pressed forward into the veins by the fresh portions of arterial blood, which move up to unite with the carbon of the tissues. If this view of the cause of the circulation is correct, it follows that the passage of the blood through the smallest capillaries should be continuous, and free from the pulsation that exists in the arteries.

Examining the circulation in a frog's foot under the microscope with a power of about 200, we find that not only does the condition of continuous motion spoken of exist, but from time to time the blood moves backward toward the arteries:

Fig. 86.

Capillary Circulation of a Frog's Foot.

a movement which, of course, it is perfectly impossible for the heart to produce, but which is readily explained by the loss of affinity of certain atoms of carbon, and increased affinity in others, attracting the blood more powerfully, and diverting it from its previous course.

The supply of venous blood to the veins by the capillaries is therefore continuous and without intermission, and the flow of the fluid in these vessels is free from all pulsatile character. According to the doctrine of Harvey, the right auricle exerts

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What facts corroborate Draper's theory? How does the blood move in the capillaries? What is the nature of the movement in the veins? What was Harvey's idea regarding the function of the right auricle?

an exhausting action on the venous blood; but, if we reflect for a moment on the yielding nature of the walls of the veins, we see that any such exhausting process is perfectly impossible.

The presence of valves in the veins, on the existence of which Harvey founded his doctrine of the circulation, does not in any way contradict or interfere with the theory of Draper, for their function is still the same; and, since they are found altogether in the extremities, where the veins are subjected to great pressure during the violent contractions of the surrounding muscles, they are absolutely necessary in order to prevent the regurgitation of the blood back upon the capillaries.

In the pulmonary circulation, the conditions which produce the movement of the blood are exactly the opposite of those which cause the systemic circulation. The blood delivered to the pulmonary capillaries is laden with carbonic acid; the air-cells, on the walls of which these capillaries are distributed, are filled with oxygen gas, which endosmoses through the walls of the vessels, and, interchanging with the carbonic acid of the blood, arterializes it.

As fast as the venous blood surrenders its carbonic acid in the pulmonary capillaries, it also loses its affinity for their walls, and is consequently forced out into the pulmonary veins by new portions of venous blood, which press forward in the capillaries to exchange their carbonic acid for oxygen. The method of operation in the lungs is similar to that in the systemic vessels, but the conditions are different—not only as regards the causes of the circulation, but also as regards the contents of the great blood-vessels; the arteries of the lungs containing venous, and the veins arterial blood, while the systemic arteries contain arterial, and the veins venous blood.

The great advantages of Draper's theory have gradually been recognized. The fact that it affords a clear, intelligible explanation of the portal circulation in the liver and kidney, and accounts for the circulation in acardiac monsters and such exceptional cases, gives it a force and power in which the doctrine of Harvey is very deficient. At the present time, therefore, Harvey is acknowledged as the discoverer of the *course* of the circulation, but to Draper is awarded the discovery of the *causes* of the circulation of the blood.

We have now described the divisions of food, and the func-

What is the function of the valves of the veins? How do the causes which produce circulation in the capillaries differ in the pulmonary and systemic vessels? Is the blood in the pulmonary artery arterial or venous? What peculiarities of circulation does Draper's theory explain that Harvey's doctrine can not?

tions of digestion, absorption, and circulation, which are engaged in preparing and delivering nutriment to the different tissues of the body; we are therefore prepared to pass to the examination of the organs of secretion and excretion. Before we take up the consideration of this division of our subject, we shall devote a short space to a synoptic review of the functions already studied. I have found such tables to be of great value to students, enabling them to fix the steps of the introduction of nutriment into the tissues more firmly in their minds, and to attain a connected idea of the various functions, and their relations to each other.

The manner in which the following tables are constructed enables the student to select any article of food, and trace it step by step to some organ or tissue. Many may object to this system, urging that the substance under question does not retain its qualities through all the processes to which it is subjected, and therefore any such method is useless. I would answer that it is not intended to assert that articles of food retain their character during the various operations of digestion and absorption; but as the experience of a number of years has taught me that this tabular arrangement is of great value to students, it is introduced here for their advantage and convenience.

In making use of the synoptic table, any special article of food, as, for example, fat, may be traced to any part of the system. It passes through the various divisions of the digestive and absorptive apparatus until it reaches the large lacteal trunks, where one portion enters the blood by the mesenteric veins and vena cava ascendens, while the other part reaches it by the receptaculum chyli and vena cava descendens. In the heart the two divisions are reunited; sent to the lungs to receive oxygen; then conveyed to the aorta, from which its course to the head, upper or lower extremities, or great abdominal organs, may be traced to its return to the right auricle.

By studying this table in connection with a few examples of different articles of food, the student will soon become perfectly familiar with all the leading facts in digestion, absorption, and circulation; for, with the passage of an article from point to point, he soon connects the changes which it under-

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Trace the course of albumen from the mouth into the right ventricle—the course of sugar to the vena cava ascendens—the course of fat to the right auricle—the course of gluten to the right hand—fibrin to the left hand—fat to the brain—albumen to the feet—salt to the kidneys. Trace the blood from the feet to the hands—from the hands to the brain—from the brain to the kidneys—from the kidneys to the liver.

STAGES OF INTRODUCTION OF INGESTA INTO THE SYSTEM.

1st, Water.	2d, Salts. Phosphate Lime, Chloride Sodium, etc.	3d, Nutritive Articles. Albumen, Fibrin, Casein, Gluten.	4th, Respiratory Articles. Carbo-hydrates = Starch and Sugar.	4th, Respiratory Articles. Hydro-carbons = Oils and Fats.
Mouth. Pharynx. Œsophagus. Stomach.	Mouth. Pharynx. Œsophagus. Stomach.	Mouth, masticated. Pharynx. Œsophagus. Stomach, digested by Gastric Juice.	Mouth, masticated and mixed with Saliva. Pharnyx. Œsophagus. Stomach, where Saliva acts, converting them into Lactic Acid, which assists the Gastric Juice in Stomach digestion.	Mouth, masticated. Pharynx. Œsophagus. Stomach, not digested, but pass through the Pyloric Valve into the Duodenum, converted into —Chyle.— Absorbed by Intestinal Villi. Lacteals. Mesenteric Glands. Lacteal Trunks, which empty into

(1st–4th, Carbo-hydrates:)

Converted into
—Chyme.—
Absorbed by Gastric Vein

(Hydro-carbons, Lacteal Trunks, which empty into:)

Mesenteric Veins.	Receptaculum Chyli. Thoracic Duct. Subclavian Vein. Vena Innominata. Vena Cava Descendens.

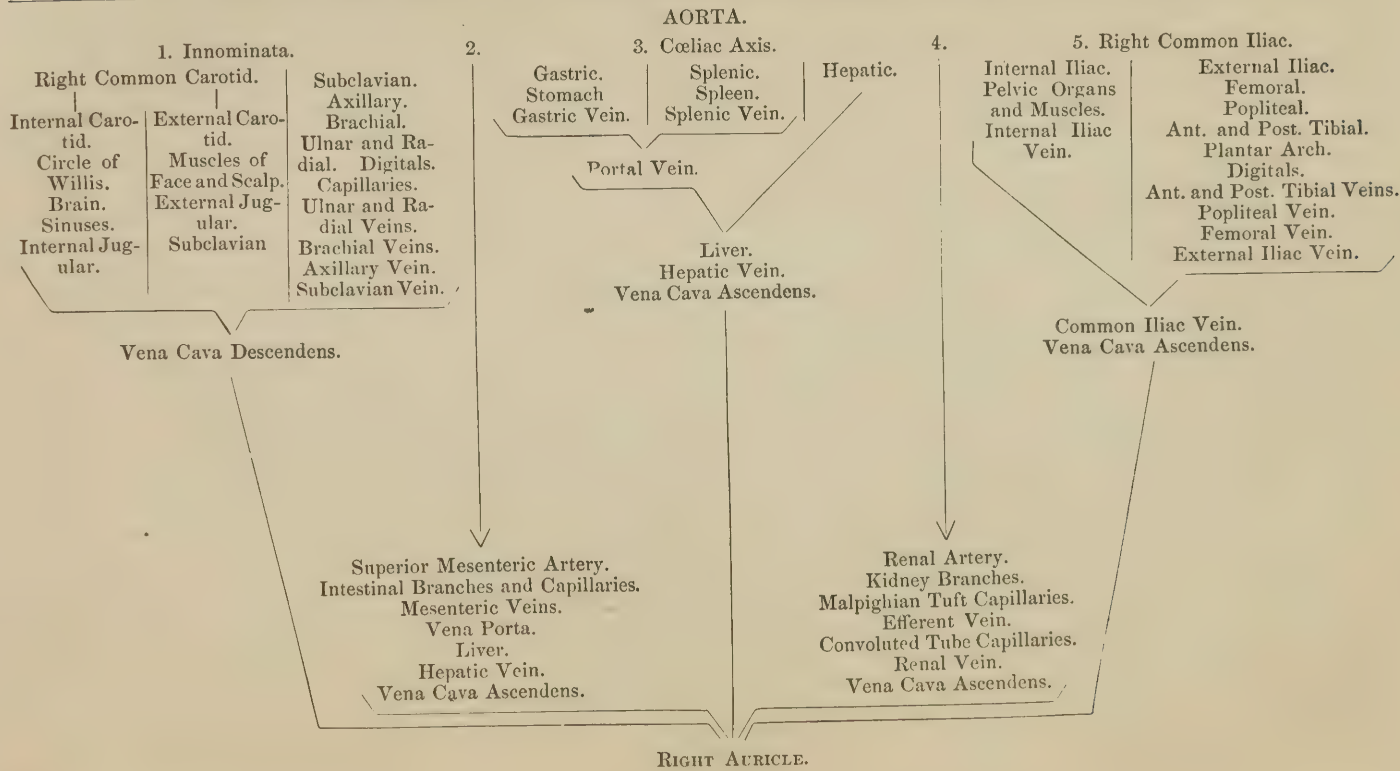
(Gastric Vein and Mesenteric Veins:)

into
Portal Vein.
Capillaries of the Liver.
Vena Cava Ascendens.

(Vena Cava Ascendens and Vena Cava Descendens:)

Right Auricle.
Tricuspid Valve.
Right Ventricle.
Pulmonary Artery.
Lungs.
Pulmonary Veins.
Left Auricle.
Left Ventricle.
AORTA.

COURSE OF BLOOD FROM THE AORTA TO DIFFERENT TISSUES AND ORGANS.



goes at each step, and they all become associated together in his memory.

Having completed the examination of the nutritive processes, we next pass to the study of the mechanisms by which the effete materials that have arisen during the action of the various tissues of the body are removed from the system; we therefore commence the consideration of the organs of secretion and excretion.

LECTURE XX.

SECRETION AND EXCRETION.

Formation of Secretions.—Structure of Glands.—Action of Spheroidal Cells.—Filtration.—The Mammary Gland.—Its Changes and Diseases.—Colostrum.—Organs of Excretion.—The Skin.—Composition and Function of the Skin.—Its Appendages.—Its Glands.—Their Functions.

SECRETION and excretion are accomplished by means of glands, which are all constructed on the same principle. The simplest form of gland is a tube, lined on the interior with a species of mucous membrane, composed either in part or wholly of spheroidal epithelium; the membrane is freely supplied with blood by an extensive and intricate system of blood-vessels.

Spheroidal cells are always employed when the gland is intended to produce a secretion containing extractive: they act by absorbing and removing from the blood substances which would, by accumulating in the system, become deleterious and produce disease. After the cell has reached its adult size, its walls either deliquesce or burst, and surrender their contents to aid in producing the secretion. The substances formed by cell action are usually very rich in carbon and hydrogen, being often fatty in their nature.

With the exception of the extractive, the other constituents of a secretion pre-exist in the blood, and are separated by filtration from the capillary plexus on the walls of the tube.

The glands which may be with propriety classified as secreting are those connected with digestion, which have already been described, together with the properties and functions of

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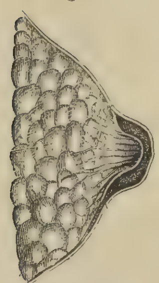
How are secretions formed? Describe the simplest form of gland. What is the peculiar function of spheroidal cells? What is the character of the bodies separated by cell action? How are the remaining constituents of the secretion separated? Where are the secreting glands found?

their secretions. To these we may add the mammæ in the female, the testicles of the male, the lachrymal, and some other small glands which have special functions in connection with certain organs, which will be described hereafter.

The mammary gland is constructed on the same plan as the salivary glands, being composed of a number of lobules, the ducts of which converge toward the nipple.

Fig. 87.

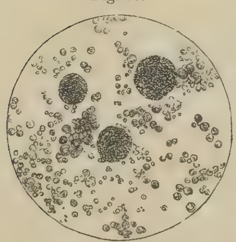


Section of Mammary Gland.

These glands undergo change at the time of menstruation, becoming hard and somewhat swollen. In pregnant women they also undergo considerable increase in size toward the close of the period of gestation, the milk often appearing before the birth of the child. The mammary gland is peculiarly liable to cancer, the deposit taking place with greater frequency in the breasts than in any other organ.

The first portions of milk discharged from the nipple after delivery contain a great number of large cells, called colostrum corpuscles. They seem to give to the milk a purgative property, which enables it to remove from the intestines of the newly-born infant the meconium, or fœtal bile which has accumulated during the last months of intra-uterine life.

Fig. 88.



Colostral Corpuscles of Milk.

The organs of excretion are the skin, lungs, and kidneys, to which we may add the spleen, liver, and some small glands connected with special functions.

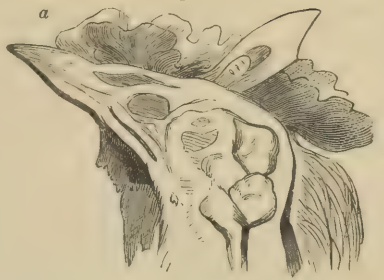
The skin consists of two distinct layers. The external, composed of pavement epithelium, is continually reproduced as it is worn away by contact with rough substances, and is called the cuticle. The internal layer is called the cutis vera: from it the cuticle originates. The skin is very freely supplied with blood: it contains two sets of glands, one of which removes water, salts, and soluble substances, while the other secretes oily bodies. Many appendages, as hair, nails, and horns, are attached to the skin, and are described with it.

The vitality of the integument is so great that it may without difficulty be transplanted from one place to another, as is

Describe the mammary gland. Describe the changes to which it is liable. What disease is common in this gland? What are colostrum corpuscles? What property does the first milk possess? Name the organs of excretion. What are the layers of the skin? What are the appendages of the skin?

Fig. 89.

a



b

c

frequently done by surgeons in the performance of such taliacotian operations as the formation of a new and perfect nose to take the place of that member when it is destroyed by disease.

In *Fig.* 89, *a* is a representation of a specimen in the Hunterian Museum, in which a human tooth was transplanted into the comb of a hen, and in the course of a few days became attached and grew. In *b*, a cock's spur was transplanted to the comb of a hen, where it grew rapidly, owing to the superabundant nutrition of the part. In the third specimen, *c*, in which the spur was successfully transplanted to the comb of a cock, it grew with still greater rapidity, and assumed a spiral form. In these interesting experiments we can not but admire the ingenuity of Hunter in selecting the cock's comb as the tissue with which to experiment, for its highly arterial character afforded greater opportunity of success than any other tissue that could have been chosen.

The epidermis, or external skin, is merely for the purpose of protection; and we find that in those parts which are subjected to continued pressure it becomes thickened, so as to fulfill the purpose for which it is employed.

An excellent illustration of this fact is afforded in fevers, when the patient has been confined to his bed for a considerable period, and the epidermis is cast off from the soles of the feet, leaving them covered with a skin as delicate as that of a new-born child, and so sensitive that the first attempts to stand or walk during convalescence are productive of severe pain.

Describe the epidermis. What determines its thickness?

Fig. 90.

Skin of Palm magnified 20 Diameters.

A very good illustration of the thickening of the skin from pressure is the hard callous, called a corn, which is usually formed on the upper surface of the toes, but which is sometimes produced between them. The latter variety is exceedingly painful.

The layer of epidermis in contact with the cutis vera is composed in part of cells, which contain a considerable amount of coloring matter in the dark races. When this is removed the cutis vera presents a pink appearance, due to the great number of capillaries it contains.

The nails are produced from the cuticle, and are horny growths which originate in a fold of that membrane. The rate of increase varies with the perfection of nutrition, and it is said that the thumb nail can be reproduced in four months, but the time seems to be overestimated.

Fig. 91.

Section of Human Hair.

The hair follicles also originate in a fold of epidermis, which assumes a tube-like form, and produces a depression in the derma. Each hair takes its origin from the bottom of its own follicle, and may be considered as being composed of two parts, an internal or medullary portion, with an external epithelial covering, formed of pavement cells, which overlap each other like the scales of a fish. It is this peculiarity which enables us to cut a single hair with a sharp knife when it is held by one extremity, the edge of the instrument passing with comparative ease between the exposed scale-like margins of the cells when applied in that manner, but gliding over them, and failing to cut the hair, when it is held by the other extremity.

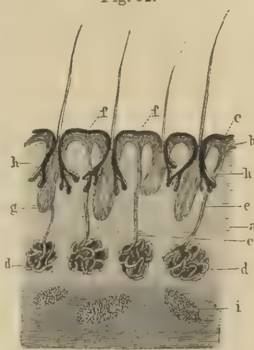
The ducts of the glands of the skin pass through the cuticle but do not appertain to it. The papillæ also, though they pro-

How are corns formed? In what part of the skin is the coloring matter of the dark races deposited? Describe the nails. How is hair produced?

ject into the cuticle or epidermis, can not be regarded as belonging specially to it.

The cutis vera, true skin, or derma, is composed of fibrous tissue, which connects it with the underlying tissues, and holds in position the blood-vessels, glands, nerves, involuntary muscle cells, and the other parts which aid in its construction.

Fig. 92.



Section of Skin magnified 10 Diameters.

In *Fig.* 92, *a* is the derma; *b*, rete mucosum; *c*, epidermis; *d*, sudoriparous glands; *e*, their ducts; *f*, their apertures; *g*, hair sacs; *h*, sebaceous glands; *i*, deposits of fat.

The sebaceous or ceruminous glands are found in the skin of all parts of the body, and usually in connection with the hair follicles. It is their office to lubricate the skin, and keep it soft and flexible; they also furnish the hair with the oily material necessary to give it a glossy look and keep it soft. The secretion of these glands is almost entirely the product of cell action.

Fig. 93.

Sudoriparous Gland magnified 20 Diameters.

The sudoriparous glands are composed of a tube, which, commencing in the skin, passes to the lowest stratum of the derma, or even to the tissues beneath, where it forms a coil, among the meshes of which blood capillaries pass in every direction. The coil and its capillaries form a small gland, the tubular portion of which is lined with pavement epithelium throughout its whole course.

The secretion of the sudoriparous glands is composed entirely of water and salts, and substances soluble in water; it is free from the extractive which exists in the secretion of other glands, and affords an interesting confirmation of the fact that spheroidal cells produce that constituent, the sudoriparous fluid lacking the extractive or fatty bodies, because the gland does not contain the peculiar cells which are necessary for the separation of such substances from the blood.

Describe the cutis vera. What is the function of the sebaceous glands, and where are they found? Describe the sudoriparous glands, their position and function. How do they act? What is the construction of the sudoriparous fluid?

The study of the glandular system of the skin presents some points of considerable interest; among these, the separation of the mere filtering mechanism, represented by the sudoriparous glands, from the proper secreting spheroidal cell of the sebaceous glands, is perhaps the most interesting, since it gives us the clew to the explanation of the action of the kidney and other organs.

The sudoriparous glands not only excrete substances from the blood, but they also absorb fluids which are brought in contact with the skin, as is demonstrated by the fact that if a thirsty person bathes himself in fresh water, his thirst quickly vanishes; and if the body is weighed before and after the bath, it will be found to have gained in weight, owing to the absorption of fluid by these glands.

By virtue of this property, various nutritive substances, as soups and stimulants, may be introduced into the system through the skin. Many medicines will also produce their special action if they are applied to the skin, as well or even better than when they are introduced into the system by the digestive canal; among these we may mention the preparations of mercury and belladonna, which have been used in this manner for many years.

LECTURE XXI.

INSENSIBLE PERSPIRATION.

Methods for determining its Quantity.—Diurnal and nocturnal Loss compared.—The Effect of Exercise.—The Substances produced by the Disintegration of Muscle when in Action escape by the Skin, and not by the Kidneys.—Relation of sensible and insensible Loss to each other.—Effect of Ingestion of Food on insensible Loss.—Diurnal Variation in the Weight of the Body.

THE amount of material excreted by the skin in the form of insensible perspiration is far greater than is generally supposed, as is demonstrated in the following paper, read by me before the New York Academy of Medicine, May 24th, 1864:

During two years' service as physician in the New York and Bellevue Hospitals, I was frequently impressed with the importance of the skin as one of the great sewers of the body,

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How is the secretion of the sebaceous glands prepared? How is it proved that the sudoriparous glands absorb as well as excrete? Can mercurial preparations be introduced into the system by any other channel than the digestive canal?

and I determined that, when opportunity offered, its duties and functions should be made the subject of study and experiment.

To carry out this intention, in the fall and winter of 1862 I constructed a balance by which the weight of the body of an adult could from time to time be accurately determined, and the variations duly noted. Considering the size of the instrument, it was very sensitive, for, when loaded with 200 pounds, the addition of one grain to the contents of either pan was instantly shown by a corresponding movement of the index. Indeed, the first difficulty with which I had to contend was the delicacy of the balance, for when it was adjusted to produce the result given above, it was impossible to use it with satisfaction; for the movement of the index was so slow, and the diminution in the weight of the body due to the insensible perspiration so rapid, that it was out of my power to arrive at a correct result. This was, however, remedied by reducing the sensitiveness in order to adapt the instrument to the work for which it was intended.

As regards the construction of the balance, it is sufficient to state that the beam was about six feet in length and two feet six inches wide at the middle, tapering gradually to the ends. It was supported at its centre on a frame-work, which raised it six feet above the floor. To one of the extremities of the beam a pan or platform was attached, on which the weights were placed, and to the other a species of chair, in which the subject of the experiment could sit in a perfectly natural, easy position, as long as was necessary.

The beam and supporting frame-work were constructed of pine wood two inches thick, that they might be as light and strong as possible. The knife-edges at the extremities of the beam, on which the pan and chair were supported, and the axis or fulcrum at the centre, were made of the best hard-tempered steel, accurately ground to give in section an equilateral triangle measuring one inch on each side. The centre axis or edge was six inches long; those at the extremities, five inches. The centre axis rested on a perfectly flat plate of hard, polished steel, while the pans were connected with the edges at the ends of the beam by means of the usual stirrup-shaped suspension pieces. In order to avoid any accident from slipping, a groove on a radius of one quarter of an inch was cut in the foot-piece of the stirrup, and carefully ground to fit the knife-edge on which it was to be supported.

The weights employed were French; but if it is desired, the

results can be readily converted into our Troy standard—1000 grammes being equal to 2·679 lbs. Troy.

Complications arising from variations in dress were avoided by wearing in all the experiments the same clothes, the weight of which was known, and of which I shall in future speak as the weighing-dress. Errors arising from variations in the time of passing the sensible evacuations were also carefully avoided. The method employed in weighing was to place on the platform a counterpoise heavier than the person to be weighed. Equilibrium was then obtained by taking small weights into the hands while sitting in the opposite pan or chair of the balance; adding this to the weight of the dress employed, and subtracting the sum from that of the counterpoise, the weight of the body at the time of the experiment was obtained. Any necessity for the presence of an assistant to watch the movement of the index was obviated by attaching to the frame of the balance a small silver reflector, in which the index scale could be seen by the person sitting in the chair.

A suitable balance being thus provided, I proceeded to the investigation of various problems connected with the weight of the body; the first that is presented is the consideration of the

Diurnal and Nocturnal Loss by Insensible Perspiration.

In order to determine the relation existing between the diurnal and nocturnal losses by insensible perspiration (under which title I have included all the insensible evacuations of the body, not only those by the skin, but also those from the lungs), a series of experiments was made, which extended throughout the month of January, 1863. The average of the results obtained is shown in the following table:

Insensible Loss per Minute.	Temperature.	Dew Point.
Day Rest........... ·79 gramme.	55°	46°
Night Sleep........ ·47 "	50°	42°

In the above the nocturnal loss is that which takes place during quiet, placid sleep, and the diurnal that which occurs when the body is kept in as perfect a state of rest as is consistent with comfort, most of the time being spent either in writing in the sitting or reading in the incumbent posture.

To the observant, intelligent physician, who has for many years endeavored to control the condition of his patients by seeking to give them sleep as well as mere muscular rest, the

What is the diurnal and nocturnal loss by insensible perspiration?

above results give the explanation of the wonderful effect which sleep has, not only in restoring the tone of the nervous system, but also in arresting the great loss of weight and the emaciation which attends so many diseases during the restless, sleepless period, but which ceases almost the moment that a calm night, in which sound sleep has been obtained, is granted to the sufferer.

For during such a night the insensible loss which is continually taking place is only about one half of that which occurs during simple muscular rest without sleep. A sound sleep usually marks the commencement of the stage of convalescence in any disease.

Having obtained in these experiments the average loss per minute by insensible perspiration during the day while in a state of rest, we shall regard it as the normal diurnal standard of loss, and proceed to examine the variations which muscular action produces.

To determine this, a number of trials were made, which demonstrate that in health, increased activity in these organs is the chief cause of increase in the rate of loss by insensible perspiration; and that in moving the body of an adult weighing 65,000 grammes one mile, 44 grammes in addition to the usual amount are lost by insensible perspiration.

The data from which the above conclusions were deduced were obtained by performing a series of experiments in which exercise, varying in duration and intensity, was undergone; and determining the increase in the rate of insensible loss, it was found to be forty-four thousandths of a gramme for every thousandth of a mile per minute of motion, as is illustrated by the following examples:

For 10-thousandths	mile	per	minute	motion,	1·16	gramme	per	minute	of	insensible	loss.
" 19	"	"	"	"	"	1·67	"	"	"	"	"	"
" 22	"	"	"	"	"	1·88	"	"	"	"	"	"
" 41	"	"	"	"	"	2·40	"	"	"	"	"	"

These examples not only bear out the statement regarding the increase in loss which follows active muscular exertion, but they also show how great an influence muscular action has in promoting the function of insensible perspiration; a movement of forty-one thousandths of a mile per minute, which is equivalent to three miles an hour, causing the rate of loss to rise from 80 to 240. Could we have indicated to us more clearly the true channel through which the products of waste and de-

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What is the effect of motion on the insensible perspiration?

cay in the interior of the economy during violent muscular action are thrown off?

In all our works on physiology, it is the received doctrine that the urea of the urine represents the results of the disintegration of the muscular, or chief nitrogenized tissue of the body. It follows, of course, that the proportion of this ingredient of the urine should increase greatly whenever the amount of muscular action is increased.

In my inaugural thesis for the degree of M.D., published in 1856 (see Lecture XXVII.), the experimental examination of this question was fully entered on, and by the use of new and more reliable methods for the determination of urea, it was demonstrated that exercise does not influence the proportion of this substance contained in the urine in the manner usually supposed, as will be seen in the following table:

For 24 Hours.	Urine.	Solid Residue.	Urea.	1000 Solid Residue contain of Urea
Average Loss...	1106·	55·584	27·213	490·
Exercise..........	905·	52·031	25·472	489·

The diurnal amount of motion in the results given under the head of average loss was about four miles a day; that under the title of exercise was thirteen miles a day. If it is true that urea is the result of disintegration of muscular tissue, we are justified in expecting to find a very great increase in the amount of that substance when long-continued exercise is undergone; but, on the contrary, not only is the quantity of urea and the amount of urine and solid residue diminished, but the proportion of nitrogenized matter contained in the solid residue also undergoes diminution, thereby showing in the most conclusive manner that the products arising during the disintegration of muscular tissue do not find their way out of the system in the urinary secretion.

The experiments of Lehmann on the influence of variations in diet, and the consideration of the relations of the diurnal and nocturnal urine to each other, furnish additional support to this opinion. Hammond also has shown that increased mental exertion is invariably accompanied by increased elimination of urea, demonstrating, as he supposes, the effect of the nervous system on the production of urea. But we may explain the increase by the fact that during mental exertion the body is kept in a comparative state of rest, in which condition

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What is urea generally supposed to represent? Is this doctrine supported by experiment? Does diet influence the formation of urea?

I have shown that there is more urea excreted than during violent exercise.

Keeping in view the facts regarding the diminution of the nitrogenized ingredients in urine during violent muscular action, we have in part the explanation of the great increase in the loss by insensible perspiration under such circumstances. Nor is there any thing surprising in the statement that the products arising during the disintegration of muscular tissue escape as insensible perspiration rather than by the kidneys, for we can not imagine any channel through which it could take place more rapidly or in a more effective manner.

In support of the opinion that the effete substances arising during the destruction of muscular tissue escape by the skin or lungs rather than by the kidneys, let any one appeal to his own experience. We all have frequently, at various periods of our lives, undergone great muscular exertion, walked perhaps fifteen or twenty miles without resting for more than a few minutes, and passed but very little urine by the way, or even none at all; the journey ended, there was no great increase in the quantity of urine, and yet our reason tells us that there must have been a great destruction of muscle in order to move a weight of 120 to 200 pounds over a distance of many miles; and we are obliged to admit that there could not be a more suitable and perfect channel for the removal of the products of muscular waste than that of insensible perspiration, either by the skin or the lungs, nor a more favorable condition than the vaporous or gaseous state.

It may also be demanded how we can explain the great congestion of the skin which almost immediately supervenes on exercise, except by supposing that effete materials are being rapidly voided; and increased congestion is necessary, in order to produce increased activity in any organ. The mere statement that the great flow of blood to the skin is only for the purpose of reducing the temperature by evaporation is not altogether satisfactory.

Organic tissues decaying or burning, oxidizing slowly or rapidly, disappear in the form of gases or vapors, as carbonic acid, ammonia, and nitrogen. In animals we know that carbonic acid is given off, and the presence of ammonia, nitrogen, and other inorganic and organic compounds as constituents of the secretions both of the skin and lungs has been demonstrated

What facts support the theory that the loss by muscular action is through the skin, and not by the kidneys?

by Berzelius and other chemists. The organic compounds are especially to be noticed as causing the death-like, sickly odor which pervades the closed wards of a hospital, or which exists in the apparatus in which experiments on respiration have been conducted.

The consideration of these facts affords sufficient justification for advancing the opinion that the products of the disintegration of muscular tissue find their way out of the system, not through the urinary apparatus, but as insensible perspiration from the lungs and skin; and the great increase in the insensible losses caused by violent exercise is in great part due to the evacuation of the products of muscular waste through those channels.

While we are considering the evacuation of effete material in a form which is not appreciated by the senses, it becomes a matter of interest to determine whether the loss due to muscular action ceases as soon as the exercise ceases, or is continued for some time afterward. In order to answer this inquiry, I made a series of experiments in the months of February and July, 1863. The rate of loss before exercise was first determined. I then walked on different occasions distances varying from one to five miles, and by weighing as soon as I returned, obtained the loss during the exercise. I then weighed at intervals of twenty minutes, so as to find at what time the rate of loss became the same as before the exercise was undertaken.

The results obtained showed that the rate of loss is increased for some time after exercise, and it is necessary that about an hour should elapse before the standard is regained; as illustrations, a couple of experiments are given. The average rate of loss per minute in the state of rest was ·79 grammes.

Rate of loss per minute after violent exercise.

No. I. First (20 minutes), 1·25. Second (20 minutes), ·91. Third (20 minutes), ·76 grammes.

No. II. First (20 minutes), 1·65. Second (20 minutes), 1·00. Third (20 minutes), ·90 grammes.

Both of these experiments show a steady decrease in the rate of loss after the exercise ceased. In the first, at the close of one hour, the insensible loss had not only reached, but had even fallen below the normal standard, ·79; while in the second, in which the loss was greater, it had not quite reached the standard. From the variations in the amount of insensible perspiration caused by exercise, we now pass to the consideration of

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Does the increased loss caused by muscular action cease as soon as exercise ceases?

The Relations of the Insensible and Sensible Losses to each Other.

Among those who have devoted time and study to this subject, no one is more worthy of mention than Sanctorio. In his work "Medicina Statica," published in 1720, the reader will find many facts which would be considered ornaments to the pages of any of our modern scientific journals; and though he had to contend with numerous difficulties, and his writings bear the impress of the times in which he lived, yet his work was a grand step in the right direction, for he made the attempt to bring the great questions of physiology to the test of the balance, and force from nature truthful but unwilling answers.

From the Aphorisms of Sanctorio we extract the following, in order to demonstrate how highly he esteemed the subject with which we are dealing.

"*Aphorism* 2.

"If a physician who has the care of another's health is acquainted only with the sensible supplies and evacuations, and knows nothing of the waste that is daily incurred by insensible perspiration, he will only deceive his patient, and never cure him."

In order to enforce the truth and importance of the above, he gives the results of his experiments, obtained by the balance:

"*Aphorism* 6.

"If eight pounds of meat and drink are taken in one day, the quantity that usually goes off by insensible perspiration in that time is five pounds."

In evidence of the close and earnest manner in which Sanctorio examined the various phenomena connected with our subject, I quote the following:

"*Aphorism* 56.

"The body does not perspire at all times alike; for in the first five hours after eating there wastes about a pound, the next seven hours about three pounds, and from the twelfth to the sixteenth (at which time there will be need of a fresh supply) nearly half a pound."

"*Aphorism* 65.

"Even those men who are in a perfect state of health, and

observe the utmost moderation in living, once in a month increase beyond their usual weight to the quantity of one or two pounds, and at the month's end return again to their usual standard, in the same manner as women do, but then by a critical discharge of urine, it being either increased in its quantity or more turbid."

The above bear the impress of the mind that originated them; and though Sanctorio has in his book added many other aphorisms which we now know must have been purely ideal, still these and many others, which we have neither time nor space to quote, give evidence of deep thought; and when we take into consideration the times in which he wrote, we can almost forget the mixture of ideal fancies with experimental results.

Passing to the consideration of the relations of the insensible to the sensible losses, and taking the period of sleep as presenting conditions which are free from external influences, we find that the insensible loss by the lungs and skin is greater than the sensible loss by the kidneys, as is shown in the following table:

Insensible loss per minute,	·47 gramme.	Temp., 50°.	Dew Point, 42°.
Sensible " " "	·40 "	" "	" " "

Not only is the insensible loss greater than the sensible by the kidneys during the night, but the same relation exists throughout the twenty-four hours, as we shall find if we compare together the total diurnal amount of these excretions.

Before giving the results of my own experiments on this subject, I shall recapitulate briefly what has been done by others who have made these excretions a subject of study.

Sanctorio, as we have just seen, states that if the ingesta in one day amount to eight lbs., no less than five lbs. find their way out of the system in the form of insensible perspiration.

Seguin made the attempt to determine the loss through the skin by inclosing himself in an air-tight bag, and ascertaining the rate of loss with the bag and without it, the difference representing the loss through the skin, which he found was 2·75 pounds per diem. He also found that the loss by the lungs being 7, that by the skin was 11.

Valentin obtained, as the result of his experiments, a loss of 2·35 pounds per diem by the skin.

What was the result of the experiments of Seguin? How were they performed? What were the results obtained by Valentin?

Many objections may be urged against experiments performed in the manner in which those of Seguin were conducted Inclosing the body in an air-tight membrane interferes seriously with the functions of the skin, and the results obtained by experiments, conducted under conditions which alter or interfere with the normal state of the body, are not to be relied on unless they are sustained by others which give similar results, and against which such objections can not be advanced. Seguin, inclosed in his air-tight bag, must really have obtained results which represented the body while in a vapor-bath at over 90° Fah., which is not by any means its normal condition. And not only was the temperature and state of moisture of the air changed, but the escape of the various excreta interfered with, and consequently the rate of loss changed from the normal standard.

In my experiments, all such sources of error have been carefully avoided; the body has always been in the normal condition — during the day employed in the usual avocations, at night at rest in bed.

In the spring of 1856 I made several experiments on my own person, in order to determine the loss by insensible perspiration through the respiratory apparatus. I have thought that it would add to the interest of this portion of our subject if they were grouped with those on perspiration through the skin and the sensible evacuations, viz., fæces and urine, and compared with the ingesta, which have also been subjected to examination. Carrying out this idea, we will first recapitulate the results of the experiments on respiration, and then pass to the consideration of the amount of liquid and solid food introduced into the system each day.

The average of many experiments showed that the number of respirations per minute being 16, and the dew point of the breath 94°, the volume of each respiration was 38·8 cubic inches, and the diurnal insensible loss through this channel 464 grammes. These results were published in the New York *Medical Times* for July, 1856.

The loss by the skin was obtained by deducting the loss by the lungs (464 grammes), given above, from the total loss by insensible perspiration, 1108, which gave as loss by the skin alone 644 grammes.

The loss by urine for my own person I determined, and published in my thesis many years previously. A few experi-

What were the results obtained by this plan?

ments were made, in order to find whether it had undergone any change; as it was materially the same as then obtained, I discontinued my experiments and adopted the old standard, which was 1106 grammes per diem.

The amount of fæces passed was also determined by weighing before and after the discharge. The average per diem quantity was found to be 159 grammes.

In the experiments made on the ingesta, care was taken not to eat or drink any thing except at the regular meals. Then, by weighing before and after eating, and making due allowance for the insensible loss during each meal, the quantity consumed was accurately determined.

The average of results, extending over a period of more than a month, gave the following quantities: Breakfast, 386; Lunch, 380; Dinner, 1231; Tea, 376. Total per diem, 2373 grammes.

Collecting these results together, we obtain the following table, which shows at a glance the diurnal amount of sensible ingesta, and the manner in which the food and water are finally disposed of by the system.

Ingesta.		Egesta by		
Breakfast	386	Skin	644	Insensible, 1108.
Lunch	380	Lungs	464	
Dinner	1231	Urine	1106	
Tea	376	Fæces	159	
	2373 grammes.		2373 grammes.	

Converting the above into Troy pounds, we find that the diurnal amount of food and liquor taken is about 6·36 pounds, of which 2·97 pounds are lost through the skin and lungs, and constitute the insensible perspiration of Sanctorio. It will be remembered that the statement he made was, that out of eight pounds of food and liquid taken into the system, five pounds pass off as insensible loss. Though the above results do not confirm his figures, they support and bring prominently forward the great importance of the losses through this channel, and the necessity of devoting more attention to the study, not only of the amount, but also of the composition of the insensible losses, before we can clearly comprehend the physiological operations and pathological changes in the human system.

In the following table the results of my experiments are compared with those of others who have made the excretions of the body the subject of examination and study:

Compare the sensible with the insensible loss.

	Ingesta.	Loss by Skin.	Loss by Lungs.	Total Insensible Loss.
Sanctorio	8 lbs.			5 lbs.
Seguin		2·75 lbs.	1·75 lbs.	4·50 lbs.
Valentin		2·35 "		
Krause		2·15 "		
Draper	6·36 lbs.	1·72 "	1·25 "	2·97 "

On submitting the above to examination, it will be found that my results agree with those of Seguin in confirming the statement that the loss by the skin is greater than that by the lungs, though the proportion was not so much in favor of the skin as it was in his experiments. The difference is probably due to the manner in which his results were obtained, viz., by the use, as before stated, of an air-tight bag, which must have stimulated the action of the skin by cutting off the loss of heat through evaporation, and so, by congestion, elevating the temperature of the body, and thereby increasing the insensible loss, just as when we take a vapor-bath the loss is greatly increased, and perspiration in the sensible form of sweat literally pours off the body.

Effect of Ingestion of Food on Insensible Perspiration.

In the examination of this subject, we shall first take up the consideration of the effect on the nocturnal loss of taking food in larger quantities and later in the evening than is customary, and then show the difference in rate of loss before and after meals.

Variation in the regular time of taking the last meal, or change in the character of the food, impresses a change on the nocturnal loss, as is demonstrated by the fact that on one occasion, after a late hearty dinner, it rose to ·77 gramme per minute, and in two other instances, when a light supper was taken, to ·55, the average being ·47. From this we conclude that the ingestion of food causes an increase in the rate of insensible loss.

If we examine the rate of loss before and after a meal, the body being kept in a state of rest, we obtain evidence in support of the above statement. During the month of January, my experiments were so arranged as to give the rate of loss in a state of rest before and after dinner. The averages of the results obtained show a difference of ·02 gramme; the rate before dinner being ·79, while that after dinner was ·81.

With Sanctorio, I therefore agree that the taking of food influences the rate of loss by insensible perspiration, but the increase in loss after a meal, as obtained in my experiments, is far less than that obtained by him.

What is the effect of ingestion of food on the rate of insensible perspiration?

Variations in the Weight of the Body from Day to Day during extended Periods.

Both Gall and Levy hold the opinion that in men there are periodical manifestations similar to those existing in females, which are scarcely visible in robust individuals, but are often very evident in those of feeble constitutions, or in persons who are suffering from fatigue following hardship. Hammond also states that he has noticed the same variations in many of his friends, the monthly manifestations being in the form of headache, epistaxis, diarrhœa, etc.

In order to arrive at a just conclusion regarding this portion of our subject, I extended my observations on the weight of the body over a period of three months, so as to obtain sufficient data from which some reliable statement could be deduced.

The greatest care was taken to weigh as nearly as possible at the same hour of the day in the different experiments. The time chosen was half past seven A.M., that is, shortly after rising in the morning. All irregularity regarding the evacuations was scrupulously avoided. The results are given in the following table, together with the temperature and dew point. The average weight for each month is also stated.

April, 1863.

Date.	Weight in Grammes.	Temperature.	Dew Point.	Date.	Weight in Grammes.	Temperature.	Dew Point.
18	64·155			24	63·710		
19	64·145			25	63·417		
20	63·520			26	63·790		
21	63·475			27	63·713		
22	63·693			28	63·615		
23	63·375			30	63·895		

Average Weight during April, 63·709 grammes.

May, 1863.

Date.	Weight in Grammes.	Temperature.	Dew Point.	Date.	Weight in Grammes.	Temperature.	Dew Point.
1	64·885			18	65·345		
3	64·007			19	65·770		
4	64·505			20	65·620		
5	65·060			21	64·420		
6	65·055			22	64·870	67	65
7	64·860			23	64·545	75	68
9	64·884			24	64·710	67	62
10	65·200			25	64·520	62	56
11	65·520			26	64·550	60	56
12	65·070			28	65·020	64	60
13	65·300			29	64·920	70	65
14	65·285			30	64·960	73	70
15	65·220			31	64·880	73	70
17	65·320						

Average Temperature and Dew Point, 68°, 64°.
Average Weight during May, 64·975.

June, 1863.

Date.	Weight in Grammes.	Temperature.	Dew Point.	Date.	Weight in Grammes.	Temperature.	Dew Point.
1	64·600	71	67	16	64·160		
2	64·300	67	60	17	64·745		
3	64·920	66	60	18	64·900		
4	65·110	65	60	19	64·600		
5	65·190	64	58	20	64·550		
6	65·120	62	59	22	65·320		
7	64·990	63	57	23	65·320		
8	64·870	64	59	24	65·095	65	60
9	64·770	66	60	26	65·820	67	63
11	64·690	71	66	27	65·345	65	60
12	65·180	70	67	28	66·120	67	63
13	65·250	67	64	29	66·870	67	64
14	65·230	65	60	30	66·290	68	65
15	64·685	70	66				

Average Temperature and Dew Point, 66°, 61°.
Average Weight during June, 65·112.

July, 1863.

Date.	Weight in Grammes.	Temperature.	Dew Point.	Date.	Weight in Grammes.	Temperature.	Dew Point.
1	65·190	71	67	11	65·390	75	75
2	66·220	73	70	13	66·190	72	71
3	66·350	73	67	15	65·650	70	67
4	65·970	73	72	16	65·470	75	73
5	65·510	70	66	18	65·695	70	67
6	65·920	71	68	19	65·685		
7	66·320	71	67	21	65·205	72	70
8	65·345	75	72	22	65·520	67	65
9	65·250	74	70				

Average Temperature and Dew Point, 72°, 69°.
Average Weight during June, 65·755.

From these experiments, we find that though there is at times an increase in weight, and variations from day to day also exist, they do not appear to be reducible to any special order, or referable to any particular cause, but are irregular, and do not demonstrate the law which Sanctorio gives in his 65th Aphorism—that in men in perfect health there is a monthly increase in weight, and also a diminution marked by a critical discharge. They do not even establish with complete satisfaction the extent to which changes in the dew point affect the weight of the body. The only fact that is satisfactorily shown is, that during the period of the experiments, viz., from April 18th to July 22d, there is an increase of weight each month, which is probably due to the decrease in physical exercise during the hot weather.

Reviewing the results we have obtained, we conclude:

1st. That the effete materials arising during the disintegration of muscular tissue are evacuated as insensible perspiration,

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Is there any loss in men similar to that in women represented by menstruation?

and not as urea through the urinary apparatus, a definite time being required after long-continued exercise before the insensible losses regain the normal standard.

2d. That the loss by the skin and lungs is greater than that by the kidneys.

3d. That we can not establish the existence of a regular monthly increase in weight, as supposed by Sanctorio and others.

LECTURE XXII.

RESPIRATION.

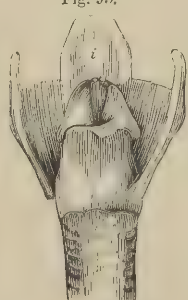
Divisions of the Respiratory Apparatus.—The Larynx.—The Trachea.—The Bronchi.—The Air-cells.—The Lungs.—The Divisions and Membranes of the Lungs.—Rate of Respiration.—Action of the Lungs.—Stages of Inspiration.—Diffusion of Gases.—Influence of Membranes on Diffusion.

We have seen in the preceding paper that nearly one half of the insensible loss to which the system is subject occurs through the channel of the lungs; we therefore pass to the consideration of the structure and functions of the respiratory apparatus, which consists of the larynx, trachea, bronchi, and capillary bronchi, which, with the air-cells, form the lungs.

Fig. 94.

Side View of Larynx.

Fig. 95.



Back View of Larynx.

The larynx is a pyramidal-shaped box, formed of cartilage, lined with mucous membrane. It contains the organism by which the voice is produced, and lies in front of the pharnyx, so that the food passes over the top of the larynx to reach the pharnyx, or entrance to the digestive apparatus. In order to prevent water and solid food entering the larynx, it is furnished with a valve, *i*, called the epiglottis, which closes the entrance to the air-passages during deglutition.

The trachea passes from the larynx to the cavity of the chest. It consists of a number of rings of cartilage, which are

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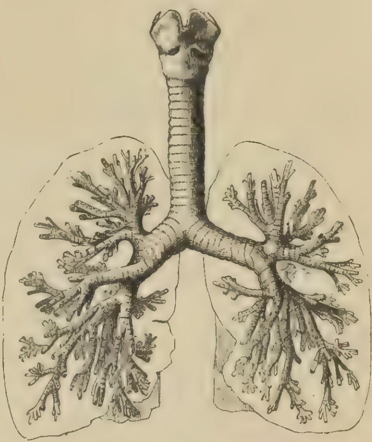
What is the relative loss by the skin and lungs compared with that by the kidneys? What are the divisions of the respiratory apparatus? Describe the larynx. What is its position? How is food kept from dropping into it? Describe the trachea.

connected by membrane, forming a tube with stiff walls, which can resist the pressure of the muscles of the neck, and prevent the closure of the air-passages during their action.

Fig. 96.



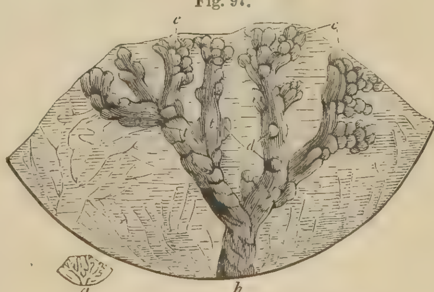
Trachea, Bronchi, and Bronchial Tubes.

Reaching the thoracic cavity, the trachea divides into the right and left bronchi, one passing to each lung. The right bronchus is shorter, wider, and more horizontal in its course than the left; it is about one inch in length, and divides, as it enters the lung, into two branches. The left bronchus is about two inches long; it divides into three branches, and forms nearly a straight line with the trachea; consequently, when foreign bodies fall into the respiratory tubes, they are more liable to pass into the left than the right bronchus.

Both the great bronchial tubes, like the trachea, consist of rings of cartilage united by a membrane composed of elastic and muscular fibres. This form of construction is retained until they reach the lungs, and subdivide into the branches which pass into the lobes.

The bronchi continue to subdivide after they reach the lungs, until finally tubes of very fine calibre are formed: these are called capillary bronchi. Each capillary bronchus terminates in a cluster of air-cells, which form a lobule. The bases of the lobules are marked by the network of lines which is visible on the exterior of the lung. The cells of the same lobule intercommunicate freely, but the cells of different lobules can only communicate through their respective capillary bronchi.

Fig. 97.



Capillary Bronchi and Air-cells of a Lobule.

In *Fig.* 97, *a* represents the natural size of the section of lung tissue which is magnified 9 diameters at *b*,

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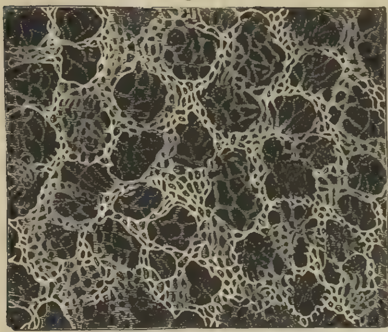
Describe the bronchi. What are their subdivisions? What are the air-cells? What are the lobules? Do the air-cells communicate?

Fig. 98.

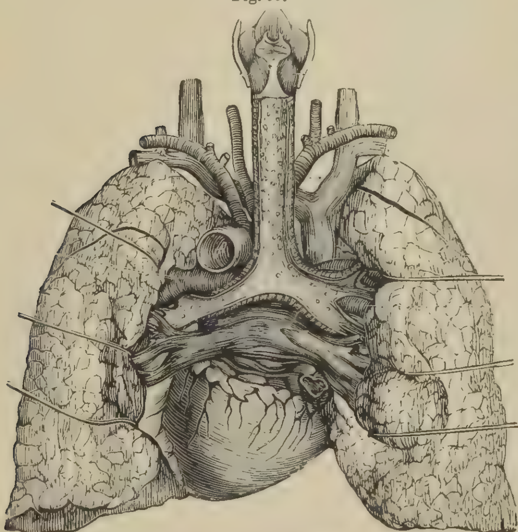


Capillary Blood-vessels of Air-cells.

to illustrate the air-cells, *c*, and capillary bronchi, *t*.

The air-cells vary in diameter from $\frac{1}{200}$ to $\frac{1}{50}$ of an inch. They are composed of a membranous wall, furnished with involuntary muscle-cells, and lined with mucous membrane, which is provided with ciliated epithelium. On the walls of the cells, and between them, the capillary vessels of the pulmonary system are distributed: they are about $\frac{1}{3000}$ of an inch in diameter, so that the blood discs can pass through with comparative freedom.

Fig. 99.



Relative Position of the Heart and Lungs.

The lungs are composed of the bronchi, air-cells, and blood-vessels. They are placed on the sides of the thoracic cavity, the heart lying between them. They are nearly conical in shape, and held in position by the roots, which are attached to their inner sides, and are formed of the large bronchial tubes and blood-vessels which enter the organ. The right lung is divided into three lobes, and the left into two. The liver encroaches on the right lung, rendering it shorter than the left; but since the heart lies chiefly on the left side, the left lung is smaller than the right, though it is longer.

The sides of the thoracic cavity which contain these organs are composed of the ribs and intercostal muscles, while the

Describe the air-cells. What is the diameter of the capillaries of the pulmonary artery? Describe the lungs. What is their position? Of what are the roots of the lungs composed? How many lobes are there in the right lung—in the left? Which lung is the longest? which is the largest?

floor is formed by the diaphragm. A continuous serous membrane lines the thoracic walls, and is reflected over the surface of the lungs: it is called the pleura. The portion covering the walls of the cavity is designated as the costal pleura; that covering the lungs is described as the pulmonary pleura. The function of this membrane is to give the organs contained in the chest perfect freedom of movement during inspiration and expiration.

The capacity of the lungs is about 200 cubic inches, but this imparts a very faint idea of the amount of surface which the air-cells present for the arterialization of the blood. The number of respirations is about seventeen per minute, and in each inspiration seventeen cubic inches are introduced, which hardly suffices to fill the large bronchi; consequently we must seek for other forces in order to explain the final introduction of the air into the air-cells and blood.

Respiration consists of two distinct movements: 1st. *Inspiration*, by which the fresh air is introduced; and, 2d. *Expiration*, by which the foul air containing the carbonic acid gas which has been separated from the blood is voided. The act of inspiration may be divided into three distinct stages:

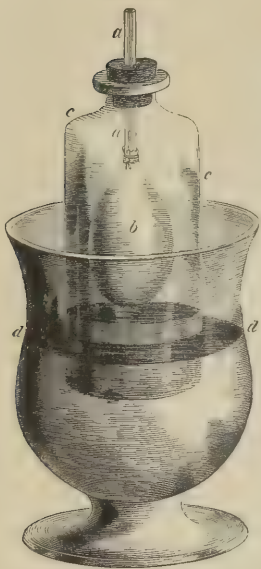
1st. *The mechanical stage*, in which the pressure of the atmosphere is called into play, and the air introduced into the large bronchi; 2d. *Simple diffusion*, by which the fresh air is introduced into the bronchi, and passes into the air-cells, while at the same time foul gas passes outward; 3d. *Diffusion through membranes* and liquids, by which the oxygen introduced into the air-cells passes through their walls and those of the blood-vessels to reach the plasma and blood discs.

In order to illustrate these movements, we call attention to certain physical phenomena, which must be understood in order to give a rational explanation of the respiratory function.

In *Fig.* 100, page 122, *c c* represents a jar, through the upper opening of which a tube, *a*, passes, which is open above, but attached below to a bladder, *b*. The jar may be regarded as representing the walls of the thoracic cavity, the bladder the lung, and the open tube the trachea, affording a free communication between the interior of the bladder or lung and the open air. Placing the apparatus in a larger vessel, *d*, filled with water, the

What tissue composes the walls of the thoracic cavity? What membrane lines the cavity? How is the portion that covers the lung designated? What is the capacity of the lungs? How many respirations in one minute? How many cubic inches in each? What are inspiration and expiration? What are the stages of inspiration? How may the first stage be illustrated?

Fig. 100.



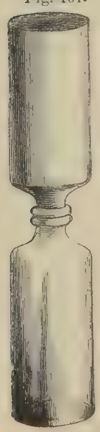
Mechanism of Respiratory Apparatus.

lower opening of the jar is closed by the fluid in the same manner that the diaphragm closes the lower part of the chest. By alternately raising and depressing the jar, we increase and diminish its capacity, and cause the bladder to expand and contract, imitating the analogous movements of the diaphragm, which, as it contracts and relaxes, increases and diminishes the capacity of the thorax, and causes the lungs to collapse and expand.

As in the preceding experiment the bladder acts in a passive manner, submitting itself to the effects of change in pressure, so the lung also acts passively, allowing the air to flow in and out with the movements of the diaphragm. The tissue composing the lung consists in part of elastic fibre, which assists to a slight extent in emptying the organ of its contents, but, with this exception, the movements are purely passive.

The amount of compression and exhaustion exerted by the action of the diaphragm is far less than is generally supposed, being equal to about half an inch of water in each direction, or one inch total variation from the extreme of ordinary inspiration to that of expiration, as may be demonstrated by breathing with the nostrils open through a tube of large bore, one end of which is held loosely between the lips, and the other placed under the surface of water.

Fig. 101.



Simple Diffusion.

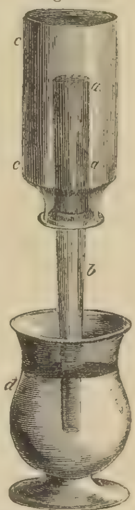
The second physical property to which we shall draw attention is the principle of diffusion of gases. If a jar is filled with vapor of ammonia by moistening its sides with that fluid, and placed mouth downward over another jar which has been filled with vapor of hydrochloric acid in a similar manner, the light gas or vapor in the upper jar passes downward into that contained in the lower jar, and, mingling with it, produces a white cloud of sal ammoniac, which is equally diffused throughout both vessels.

Does the lung move actively or passively? What is the amount of pressure called into action in inspiration? What is simple diffusion of gases? How may it be illustrated?

To this phenomenon the name of diffusion of gases has been given, and it is shown by all gases that have been submitted to experiment. It is not produced by gravity, but takes place against it, as was demonstrated in the experiment related above, where the light gas moved downward, and the heavy one upward, in order to produce a uniform mixture.

By virtue of this principle, the pure air which was introduced by the first or mechanical act is carried into the air-cells, and the carbonic acid of the cells at the same time passes outward, to mingle with the air in the bronchial tubes, and be ejected by the act of expiration. The introduction of fresh portions of oxygen into the cells constitutes the second stage of inspiration.

Fig. 102.

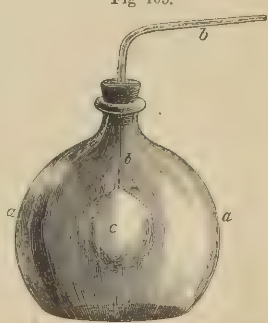


Diffusion of Gases through porous Barriers.

Not only will gases mutually diffuse when they are freely exposed to each other, but the same effect is produced with equal or even greater facility when they are separated by a membrane.

If the porous jar, *a a*, in the figure, is filled with air, and then covered with a vessel, *c c*, containing coal gas, the contents of the porous jar are greatly increased by the passage of the gas through its walls, as is shown by the fluid in the glass tube *b*, attached to the jar, being depressed toward *d*. If the vessel containing the gas is removed, the movement immediately ceases, and then commences in the opposite direction; the gaseous contents of the jar diminish in volume, the fluid rising in the tube to occupy the vacant space.

Fig 103.



Diffusion through poreless Structures.

Through the walls of poreless structures the same movements of gases occur, as may be demonstrated by taking a bottle, *a a*, moistening its inner walls with aqua ammonia to fill it with the vapor of that liquid, and then blowing a soap bubble, *c*, in the interior of the jar by means of a tube, *b*, loosely fitted to its mouth by a cork. If to the open projecting end of the tube we approach the stopper of the hydrochloric acid bottle

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How does gravity influence the diffusion of gases? How is the second stage accomplished? What is the influence of interposing membranes on the diffusion of gases? Explain the experiment with the porous jar. Explain the experiment with the soap-bubble.

as soon as the mouth is removed, we find that a cloud of chloride of ammonium is produced, showing that the ammoniacal gas contained in the bottle has passed through the walls of the bubble to mingle with the gases from the lungs which it contained; and, reaching the open extremity of the tube, its presence is indicated by the test employed.

Fig. 104.

Diffusion against pressure.

The force with which a gas will penetrate such thick, strong, resisting membranes is perfectly irresistible. The experiment, *Fig.* 104, consists in taking a stout tube of glass, *a b*, through the bottom of which a couple of platinum wires, *b c*, pass, which can at pleasure be made to communicate with the poles of a Voltaic battery. The tube is partially filled with water, *e e*, and a pressure-gauge, *d*, and suitable stand or support introduced, on which a slip of paper moistened with nitrate of lead is placed. The mouth of the apparatus is then closed with a stout piece of India-rubber, *a a*, and the platina wires are brought in contact with the poles of a Voltaic battery. The passage of the electric current causes the water to undergo decomposition, hydrogen and oxygen being evolved, which, since their escape is prohibited by the India-rubber, exert pressure, as is shown by the rise of the index fluid in the pressure-gauge. When a pressure of five or ten atmospheres is reached, the India-rubber is covered by a jar containing sulphureted hydrogen; the gas in an instant penetrates the membrane which separates it from the gases contained in the tube, to unite with them, its passage and presence in the mixture of oxygen and hydrogen being indicated by the blackening of the slip of paper. Increasing in other trials the pressure in the tube, the movement takes place with equal facility; we therefore conclude that pressure does not influence the diffusion of a gas through a membrane.

Can pressure influence diffusion through membranes? How may it be demonstrated?

LECTURE XXIII.

RESPIRATION—*Continued.*

Second and third Stages depend on Diffusion of Gases.—Stages of Expiration.—Difference between inspired and expired Air.—Experiments on Respiration.—Object of Respiration.—Diseases affecting the Respiratory System.

The experiments we have related furnish us with the explanation of the movement of the air from the air-cells to the blood discs. The tissues or membranes through which it is obliged to pass are exceedingly thin, being the delicate wall of the air-cells, that of the blood capillary, and the blood disc. Through these the oxygen passes instantaneously, and, reaching the hæmatin, is dissolved by it, and changes the color of the disc from blue to red.

At the same time, the carbonic acid, which has been held in solution in the plasma by the aid of phosphate of soda, is surrendered to the air-cell, and carried out of the system by a movement the inverse of that which introduced the oxygen gas.

If we allow atmospheric air to come in contact with lime-water, it will, after the lapse of some hours, produce a pellicle of carbonate of lime on the surface of the liquid; but if we pass the air from the lungs through another portion of the same specimen of lime-water, it immediately produces a copious precipitate, thereby demonstrating that the expired air contains a far greater proportion of carbonic acid than atmospheric air. By careful chemical analysis it is found that air contains only one part in two thousand of carbonic acid, while the expired gases contain from three to four per cent. With the increase of the carbonic acid in the expired air, there is also a diminution in the proportion of oxygen amounting to four or six per cent.

Some years since I made a series of experiments on the function of respiration, which are of interest, as they deal with cer-

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Apply the principles of diffusion to the introduction of oxygen into the blood discs. What are the stages of expiration? What is the difference between inspired and expired air? How may it be demonstrated? What is the proportion of carbonic acid in fresh atmospheric air? What is the percentage in expired air? What is the loss of oxygen in expired air?

tain points, such as the quantity of air introduced and the amount of moisture exhaled through this channel; they were published in the New York *Medical Times* for July, 1856. The questions which that article discussed were,

1st. What is the quantity of air exhaled in one minute?

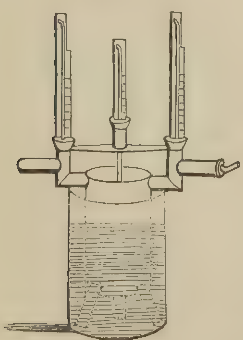
2d. What is the influence of rapidity of respiration upon this quantity?

3d. What is the amount of water excreted by the lungs in one minute?

4th. What is the influence of the rapidity of respiratory movement on this quantity?

Many solutions have been given of the above inquiries, from the long-received assertion that there are seventeen respirations in one minute, and seventeen cubic inches in each, to the recent experiments of Vierordt, which show that there are sixteen respirations in a minute, and thirty and a half cubic inches in each. Nor is it difficult to account for the great discrepancies which occur in these statements, when we consider the manner in which some of the experiments were made; for example, in determining the amount of air, one method was by breathing into a graduated gasometer, and displacing the water contained therein. But when we recollect that the normal disturbance of pressure taking place during placid respiration is equal to only one inch of water, we see how great an influence this method of performing the experiment would have in falsifying the results.

Fig. 105.



Another element of error was the duration of the experiments; in some, the quantity contained in a single expiration being determined, while in those of Vierordt, which are the best we have, the time was only one minute.

In order to avoid these sources of error, the apparatus *Fig.* 105 was resorted to.

The air, as it escaped from the mouth, was conducted into a metallic vessel, kept at 32° Fahrenheit by placing it in a mixture of ice and water; here its moisture was deposited, on account of the decreased temperature. A thermometer was placed in the tube which

What are the objections to the methods formerly employed in determining the quantity of air introduced in inspiration? How may these be avoided?

carried the air out of this condenser, as we may call it, and thus the temperature of the escaping air was known.

It is evident that by the use of such an instrument all error caused by the influence of pressure was avoided, for it required no more effort to expel air through its cavity than it does to drive it through the trachea and the narrow chink of the glottis. From the increased weight of the condenser, the amount of water collected during an experiment was determined.

Having obtained the weight of water, and the temperature of the air as it escaped from the condenser, it remained to determine the dew point of the air as it escaped from the mouth, when, by means of the following formula, the volume of air expired in a given time could be calculated: As the weight of water in one cubic foot of air at the dew point of the breath, minus the weight of water in one cubic foot of air at the temperature of that escaping from the condenser, is to 1728 cubic inches, so is the weight of water in the condenser to the quantity of air expired.

In order to avoid the error of time, which has entered into the researches of other observers, each experiment was continued for the space of twenty minutes, and from this the amount per minute was calculated. Having thus avoided the most important causes of error, we proceed to give the results of some observations made upon the above principles; and, first,

Of the amount of Air expired in one Minute.

Number of respirations in one minute, 16.
Dew point of breath, 94°.

Experiment 1	619 cubic inches.
" 2	618 " "
" 3	640 " "
" 4	615 " "
" 5	621 " "
Average per minute	622 " "
Volume of each respiration	38.8 " "

From this we find that when respiration was carried on at its normal rate of sixteen movements in a minute, the experiment lasting for twenty minutes, 622 cubic inches were exhaled in one minute, and $38\frac{8}{10}$ cubic inches constitute the volume of each respiration, representing the physiological condition of the function. Let us now see the influence of decreased rapidity.

In order to obtain a minimum, I breathed during the same space of time as in the former experiments, but at the rate of only six movements in a minute, each act being as much retard-

At the rate of sixteen respirations per minute, what is the amount introduced at each inspiration by this method?

ed as possible, thus seeking to obtain the smallest amount of air which would satisfy the system during a somewhat lengthened period of time. The results of the observations were as follows:

Number of respirations in one minute, 6.

Experiment 1	508	cubic inches.
" 2	486	" "
" 3	541	" "
Average per minute	511	" "

It still remained to determine the amount exhaled when respiration is hurried, and each act as full as it is possible to make it under such circumstances, thus obtaining the greatest volume of air that can be introduced into the lungs per minute, the experiment being continued for twenty minutes.

The result of one trial gave the following:

Number of respirations per minute, 33.

Experiment	1077 cubic inches.

From the foregoing results we obtain the following table:

No. of Respirations.		Cub. in. per min.
6.	Least amount sufficing for wants of system	511
16.	Average demand	622
33.	Utmost extent of respiratory operation	1077

From which we conclude,

1st. The amount of air in each normal respiration is $38\frac{8}{10}$ cubic inches, the number of acts being sixteen per minute.

2d. The amount of air introduced into the system depends, for the most part, on the rapidity with which respiration is carried on.

Of the Water exhaled in one Minute.

For the solution of this problem the same instrument was used as in the experiments given above, and the method of procedure was the same.

The results of four experiments were as follows:

Number of respirations in one minute, 16.
Dew point of breath, 94°.

Experiment 1.	Grains of water per minute	4.378
" 2.	" " "	4.539
" 3.	" " "	4.329
" 4.	" " "	4.418
Average		4.416

Effect of decrease in Rapidity of Movement.

Number of respirations per minute, 6.

Experiment 1.	Grains of water per minute	3.602
" 2.	" " "	3.415
" 3.	" " "	3.743
Average		3.586

Effect of increased Rapidity.

Number of respirations per minute, 33.

Experiment. Grains per minute.. 7.560

Tabulating these experiments, we obtain:

No. of respirations,	6.	Grains of water per minute	3.586
" "	16.	" " "	4.416
" "	33.	" " "	7.560

From this we find that the quantity of water exhaled also depends on the rapidity of the respiratory act.

These experiments were all continued for the same period, viz., twenty minutes. They were all made at a temperature of 56°, and a dew point of 49°. The same person was the subject of each experiment, being a healthy adult weighing 130 lbs.; and the results may be summed up in the following general conclusions:

1st. The number of expiratory acts being sixteen per minute, each contains $38\frac{8}{10}$ cubic inches of air.

2d. The amount of water exhaled in one minute at a temperature of 56°, and a dew point of 49°, is $4\frac{416}{1000}$ grains.

3d. The amount of water and air exhaled from the lungs is for the most part dependent on the rapidity of the respiratory act, increasing and diminishing therewith.

From the facts we have given regarding respiration, the reader will perceive that it must perform some function of great importance to the system, for if the lungs cease to act but for a few moments, death is the result; if we breathe a gas that is noxious, or air that contains but a very small proportion of carbonic acid, we die.

Recalling the mechanism of the lungs, and the change impressed on the air while it remains in them, we can not avoid the inevitable conclusion that the duty of these organs is to introduce oxygen into the system, and remove carbonic acid.

In a previous lecture attention was drawn to the fact that many animals not only maintain a temperature higher than that of the medium in which they live, but they also possess the power of keeping it at a fixed degree. This can only be done by means of an oxidation in the system of carbon, hydrogen, and other substances, and it is the function of respiration to introduce the necessary oxygen from the air.

How does the rate of inspiration affect the quantity inspired? What is the amount of moisture given off by the lungs? What is the influence of increased rapidity of respiration? What is the function of respiration? What facts may be advanced to prove these statements?

Other gases, with the exception of protoxide of nitrogen, will not answer, and even the protoxide can only be used for a short time. We may, it is true, for a few moments employ hydrogen or nitrogen, but they finally cause death by acting in a passive manner, and preventing the entrance of oxygen. Carbonic acid, and the great majority of gases, are not only incapable of supporting respiration, but also possess a directly poisonous effect.

Carbonic acid being one of the products of the action of oxygen on the tissues of the system, is, as we have stated, very poisonous, and must therefore be removed as fast as it is produced. This the lungs accomplish by the act of expiration, the carbonic acid being held in solution by the plasma of the blood, and so conveyed to the lungs as quickly as possible.

Before closing the consideration of the respiratory organs, it is necessary to make a few remarks regarding the diseases which affect them, since in our city a very large proportion of the mortality is caused by the diseases of the lungs and their appendages.

1st. *Croup* is an inflammation of the mucous membrane of the larynx and upper parts of the respiratory tract, attended by the exudation of lymph and formation of a false membrane, which gradually or suddenly closes the air-tubes, and so causes death; it sometimes extends down into the capillary bronchi.

2d. *Bronchitis* is an ordinary inflammation of the mucous membrane of the large bronchial tubes, which terminates in the formation of pus. The cough is loud and ringing; the pain in the front of the chest; the expectoration at first a white frothy material, but finally pus.

3d. *Chronic Bronchitis* is produced by the previous disease when it has continued for a long time, and left the mucous membrane thickened and irritable.

4th. *Capillary Bronchitis* affects the membrane of the fine tubes; it is dangerous, and causes great suffering.

5th. *Pneumonia* is an inflammation of the air-cells and tissue of the lung, attended by solidification and closure of the cells. It usually commences at the base of the right lung, and is attended by a dull soreness, cough, and the expectoration has an iron-rust color.

6th. *Pleurisy* is an inflammation of the serous membrane

How do nitrogen and hydrogen act on the system? How does carbonic acid act? How is the carbonic acid produced in the system conveyed to the lungs? What is croup—bronchitis—chronic bronchitis? What is capillary bronchitis? What is pneumonia? What is pleurisy?

covering the lung; it is attended by acute pain, so that the sufferer tries to suppress the cough as much as possible. There is no expectoration. It most frequently terminates by the pulmonary and costal pleura adhering to each other.

7th. *Consumption*, also called *Phthisis* or *Tuberculósis*, usually commences at the apex of the left lung, by the deposition in the tissue of the organ of small hard masses, called tubercles; these gradually undergo disintegration, and are converted into pus, which is expectorated, leaving a cavity. The great constitutional disturbance which accompanies the disease assists in reducing the patient, and death is hastened by the hectic fever and terrible night-sweats which often appear in the early period of the attack.

LECTURE XXIV.

ANIMAL HEAT.

Definition of Animal Heat.—Paine's Experiments on the Temperature of Plants.—Cold and hot blooded Animals.—Relation of the Nervous System to the Production of Heat.—Allotropic Condition of Carbon and other Elementary Substances.—Blushing explained.—Variations in the Temperature of the Body.—Temperatures that can be endured by the Body.

By the term animal heat it is intended to express the fact that plants, and especially animals, possess a temperature different from that of the medium in which they live. In the case of plants it is sometimes higher and at others lower than that of the air; this is in part due to the fact that the woody fibre of which they are composed conducts heat with greater facility lengthwise than crosswise. The interior of the stem of a plant therefore follows the temperature of the soil in which its roots are placed more closely than that of the air.

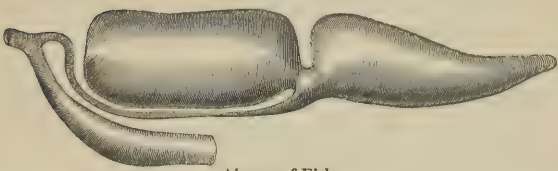
In his Medical and Physiological Commentaries, Professor Paine gives the results of experiments on the temperature of plants, which demonstrate that these organisms generate a certain amount of heat within their systems, as is shown by the following table:

Temperature of the air in the shade, 38° to 52°.
Temperature of a dead tree, 12 inches diameter, 45°.
Temperature of Juglans squamosa, 10 inches diameter, buds enlarging, 48°.

What is consumption? What is meant by animal heat? How may the internal temperature of plants be in part accounted for? What was the result of Professor Paine's experiments on the internal temperature of plants?

Temperature of Quercus tinctoria, 7 inches diameter, no budding, 49°.
Temperature of Castanea Americana, 12 inches diameter, no budding, 50°.
Temperature of Salix Babylonica, 18 inches diameter, buds unfolded, 53°.
Temperature of Pinus Canadensis, 18 inches diameter, 54°.
Temperature of Juniperus Virginiana, 4 inches diameter, 55°.
Temperature of Populus lævigata, 4 inches diameter, in bloom, 62°.
Temperature of Populus lævigata, 3 inches diameter, in bloom, 65°.
Temperature of Populus lævigata, 2 inches diameter, in bloom, 67°.
Temperature of Populus lævigata, 1¾ inches diameter, in bloom, 68°.

Fig. 106.



Air-sac of Fish.

Fig. 107.

Lung of Reptile.

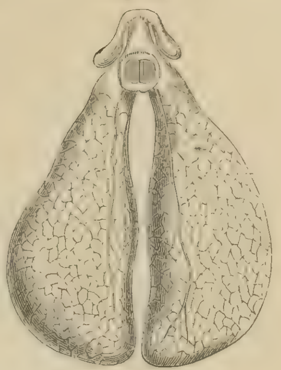
Passing from the vegetable to the animal world, we find that the lower forms of animals have a temperature but little higher than the water or atmosphere they occupy, and with the rise and fall of the temperature of the medium there is a corresponding and almost immediate change in their temperature. All the animals that present these peculiarities appertain to the cold-blooded class, which includes fishes and reptiles. In these creatures respiration is either accomplished by the skin, by gills, or by rudimentary lungs.

Cold-blooded animals, as a rule, are far more tenacious of life than those which are hot-blooded; they breathe more deliberately, and their tissues waste away far less rapidly, so that they can live for very considerable periods without food. The amount of nutriment consumed by them in a given time is much less than that required by a hot-blooded animal of equal weight. Cold-blooded creatures can also sustain with comparative ease injuries which would almost instantly destroy the life of a bird or beast, and they sometimes reproduce an entire extremity that has been lost.

Men, beasts, birds, and all hot-blooded creatures, possess the power of maintaining their temperature at a fixed degree. The respiratory apparatus reaches perfection in them; the lungs are more thoroughly divided into air-cells; the rate of respiration is more rapid, and the pulsations of the heart are more frequent, so

What is a cold-blooded animal? What is a hot-blooded animal? How is respiration accomplished in cold-blooded animals? Which class of animals are the most tenacious of life? In which class of animals is the respiratory apparatus most perfect?

Fig. 108.



Lung of the Frog.

that the blood is passed in a continuous copious stream through the capillaries.

It has been already stated that the origin of the heat in the system was the union of carbon and hydrogen with oxygen; to this we must add the oxidation of the sulphur of the muscular and the phosphorus of the nervous tissue, though the proportion derived from their combustion may be disregarded when compared with that obtained from carbon and hydrogen.

The oxidation of combustible substances goes on to a certain extent in the lungs, but the chief action is in the systemic capillaries, so that heat is produced in the innermost recesses of every tissue of the body. Any one who has ascended a lofty mountain will recollect the peculiar intensity of the cold, which seemed to penetrate to the very marrow of the bones, when the thermometer did not indicate a degree of temperature at all commensurate with the effect on the system. This is due to the fact that at great altitudes the air is rarefied to such an extent that each inspiration introduces far less oxygen than is conveyed into the system at the level of the sea, consequently there is a smaller amount of combustible oxidized; less heat is produced in the interior parts of the body, and the sensation of cold is the more intense, because the actual internal temperature is lower.

Animal heat being produced by oxidation, some process is necessary by means of which any excess of heat may be conveyed out of the system. This is accomplished by the evaporation of water in the form of insensible perspiration from the skin and lungs, as was explained in treating of the uses of that liquid in the system, water requiring an enormous amount of latent heat in order to convert it into the gaseous state.

It was formerly supposed that the heat of the body was produced by the nervous system in some mysterious manner, but we now know that, though the nervous system does not originate the heat, it regulates the rate of production.

What is the origin of the heat in the system? Where does oxidation take place in the body? Why is such an intense degree of cold experienced in ascending lofty mountains? How is the excess of heat produced in the body disposed of? What is the relation of the nervous system to the production of heat?

Chemists have shown that oxygen, as well as carbon, hydrogen, sulphur, and phosphorus, present themselves under at least two allotropic forms. In one they are prone to unite with oxygen, and in the other they are indifferent, and show little or no tendency to go into union. To the first state the term active has been applied, while the second is called the passive condition.

Electricity possesses control over the condition of these bodies, and can convert them from one state into the other. The nervous force likewise can influence the allotropic condition, as it is called, of these elements. Whenever, therefore, the atoms of carbon in any given tissue are changed to the active form, the flow of discs to supply them with oxygen is immediate, heat is evolved, and carbonic acid produced. In this manner such sudden congestions of the capillaries as that which occurs in blushing are readily and rationally explained. The true relation of the nervous system to the production of the heat of the body is similar to that which the engineer bears to his engine; he does not produce the heat in the furnaces, but regulates the rate of production.

The temperature of various orders of animals and birds is determined to a great extent by their activity. As an example, the swallow, which spends hours on the wing, catching the flies and other small insects on which it feeds, has a temperature of 110°, while the barn-yard fowl, which scarcely ever soars higher than its favorite evening perch, has a temperature of about 100°.

In man the average temperature of the body is 98°; but it varies in its different parts, decreasing as we pass from the centre of circulation to the extremities. In the viscera of the abdomen it is 101°, while in the leg it is 93°, and in the sole of the foot only 90°.

Age also possesses its influence. At the moment of birth it is about 100°, being the same as that of the uterus; it quickly falls to 99°, but soon rises to 102°, at which point it remains throughout infancy.

The variations of temperature to which the human body can be subjected with impunity are far greater than is generally

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What are the two allotropic forms? How is the allotropic condition of an elementary body influenced by electricity? Can the nervous power influence the allotropic condition? How may blushing be explained? How does the activity of an animal influence its temperature? What is the average temperature of man? What is the effect of distance from the centre of circulation on the temperature? How does age influence the temperature of the body?

supposed. The thermometer in the polar regions often indicates a temperature of 60° Fahrenheit, and yet a seaman will in the course of a few weeks pass from regions in which mercury freezes to the equator, where the temperature is 130° in the shade, without serious injury, though the change in climate has amounted to nearly 200°.

Far greater variations than these can for a few moments be borne. It is stated that a man may enter and remain for a few seconds in an oven, the temperature of which is 600°, providing the air is dry. Under these circumstances, the rapid evaporation from the surface of the body prevents the temperature rising; but if the air is moist, evaporation does not go on, and serious consequences immediately arise.

LECTURE XXV.

THE URINARY SYSTEM.

Position and Descriptive Anatomy of the Organs forming the Urinary System.—Microscopic Anatomy of the Kidney.—Portal Circulation of the Kidney.—Properties, Quantity, and Composition of Urine.—Classes of Food represented in the Urine.—Function of the Malpighian Tufts and Convoluted Tubes.—Draper's Theory of the Method of Action of the Kidney.

THE third channel by which effete substances are eliminated from the system is the urinary apparatus. It consists of the kidneys, ureters, and bladder. The bladder is situated in the pelvic cavity, and is the receptacle into which the urine passes as fast as it is secreted, and from which it is voided at the desire of the individual. It consists of a muscular bag lined with mucous membrane, and, when distended, will contain a quart of liquid, or even more. When it is subjected to too great a degree of distention it becomes paralyzed, the muscular coat in some instances never regaining its proper contractile power; the sufferer loses all control over the organ, and the urine dribbles away slowly, causing great annoyance and inconvenience.

The ureters are tubes about the diameter of a goose-quill; they pass from the bladder to the kidney. There is one on each side of the vertebral column. (See *Fig.* 81.)

The kidneys are two in number, one on each side of the

How great are the variations of temperature the body can endure without injury? What organs compose the urinary apparatus? Describe the bladder. Describe the ureters.

Fig. 109.

Section of Kidney.

spinal column, in the lumbar region or loins. They extend from the eleventh rib to the upper edge of the ileum, and are about four inches in length, two in breadth, and one inch thick. They are shaped like a bean, and in the male adult weigh from $4\frac{1}{2}$ to 6 oz., in the female from 4 to $5\frac{1}{2}$ oz. The kidney is covered externally by a strong fibrous envelope, called the capsule, over the anterior portion of which the peritoneum passes, the posterior surface being attached by cellular tissue to the walls of the abdominal cavity.

On making a section extending through the greater diameter of the organ, we find that it is composed of an external or cortical layer, 1 2, which is dark red in color, and about two lines in thickness, and an internal or medullary substance, 3 3, of a light red tint.

The ureter, 6, enters the kidney at the notch on its concave border, and expands into a conical-shaped cavity, called the pelvis, 5 5; into this cavity all the minute tubes which form the cortical and medullary portion of the organ empty. The small tubes of the kidney, or tubuli uriniferi, as they are called, commence in the cortical portion in a flask-like body, A, called the Malpighian capsule, which contains a tuft of blood-vessels, *f g h*, and is lined by spheroidal epithelium, *a c*. Leaving the capsule, the first portion of the tubule is twisted frequently on itself as long as it remains in the cortical portion; it is therefore called the convoluted tube, B C, and is lined with spheroidal cells, *b d*. As soon as it reaches the medullary portion, the tubule pursues a straight course until it empties into the pelvis of the kidney.

Fig. 110

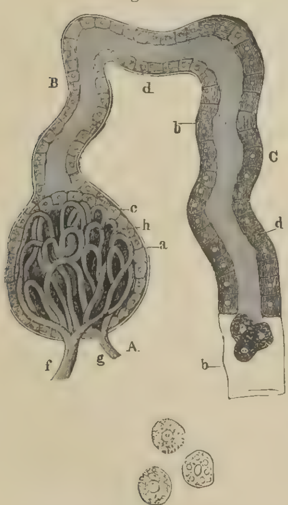

Diagram of Convoluted Tube and Tuft.

In *Fig.* 111, *a* represents the straight tubes, which originate from the convoluted tubes *b b*, among

Describe the position of the kidneys, their size and weight. What is meant by the cortical and medullary portions of the kidney? What is the pelvis of the kidney? What are the tubuli uriniferi? What is the Malpighian capsule? Describe the convoluted tubes.

which the ramifications of the renal artery, c c', are shown, and the Malpighian tufts, c''.

The circulation in the kidney presents peculiarities of considerable interest in connection with the theory of the circulation of the blood; it is therefore worthy of especial study.

Fig. 111.

Convoluted Tubes and Blood-vessels.

The renal artery, as soon as it enters the organ, commences to subdivide until the

Fig. 112.

Tuft and Convoluted Tube.

Fig. 113.

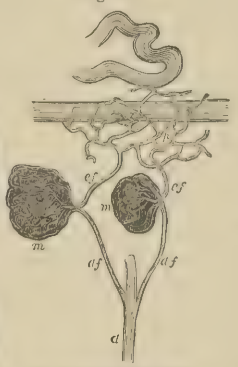

Diagram of Malpighian Circulation.

branches, *a*, *Fig.* 113, are almost capillary in their character. One of the minute branches, *a f*, enters the Malpighian capsule, and, subdividing into small branches, which are convoluted or twisted on each other, forms the Malpighian tuft, *m*. To the artery, as it enters the capsule, the name afferent vessel is given. The branches which form the tuft reunite and form a trunk, which takes its exit from the capsule close to the entrance of the afferent vessel. It is called the efferent vessel, *e f*.

As is demonstrated by the figure, the efferent vessels do not unite immediately to form the renal vein, but pass to the convoluted tubes, and, subdividing, form a capillary system or plexus, *p*, which covers their surface, and by which the spheroidal cells of the mucous membrane of the tube are nourished. These capillary vessels, reuniting, form the terminal twigs of the renal vein.

From the facts given in the preceding paragraph, we see that the kidney possesses on the small scale a circulation which re-

How is the renal artery distributed? What is the efferent vessel? Where does the renal vein commence to form?

sembles that of the liver, for the efferent vein commences and ends in a capillary system, and is the anologue of the portal vein.

Before we can intelligently discuss the function of the kidney, we must examine into the nature of its secretion.

Urine is a yellowish fluid, with a specific gravity of about 1025. When first voided it has an acid reaction, but it soon becomes alkaline, owing to the formation of carbonate of ammonia by the decomposition of the urea it contains. In the course of a day, the amount passed by a healthy man is about thirty-five ounces, but this varies greatly with the quantity of liquid that has been taken, and the amount of perspiration. In the herbivora the urine is alkaline and turbid, while in the carnivora it is like that of man, acid and clear.

The constituents of the excretion are all substances that are almost completely oxidized. The nitrogenized group is represented by urea and uric acid, derived to a great extent from the nitrogenized elements of the food. The extractive represents the respiratory group, and the chlorides were taken into the system in the same form they present in the urine, viz., common salt. The sulphates and phosphates are derived from the muscular and nervous tissues, as is demonstrated by the fact that increased action of the muscles and nervous system is followed by an increase in the sulphates and phosphates.

Analysis of Urine by Berzelius.

Water	933.00		
Urea	30.10		
Uric acid	1.00	Nitrogenized	31.42
Mucus and epithelium	.32		
Extractive and lactates	17.14	Non-nitrogenized	17.14
Sulphate of potash	3.71	Sulphates	6.87
Sulphate of soda	3.16		
Phosphate of soda	2.94		
Bi-phosphate of ammonia	1.65	Phosphates	5.59
Phosphate of lime and magnesia	1.00		
Chloride of sodium	4.45	Chlorides	5.95
Chloride of ammonium	1.50		
Silica	.03		.03
	1000.00	Solids	67.00
		Water	933.00
			1000.00

With the exception of the extractive, the substances in the preceding table are all more or less soluble in water, and pre-

What analogy exists between the circulation in the kidney and the liver? What is the color, specific gravity, reaction, and diurnal amount of urine? What is its reaction in the herbivora? Does human urine retain the acid reaction after it is passed? What groups of food do the constituents of the urine represent? What is the composition of urine? Which constituents pre-exist in the blood?

exist in the blood, as has been satisfactorily demonstrated. The soluble ingredients are easily separated by a mere act of filtration, similar to that conducted in the sudoriparous glands; and since we can without difficulty find in the sudoriparous secretion the chlorides, phosphates, sulphates, and urea of the urine, we accept the theory that these substances are separated by the Malpighian tuft, which is analogous to the sudoriparous gland in its structure as well as in its function. With the extractive of the urine the case is different; the substances composing it do not pre-exist in the same form in the blood; they partake of the fatty nature, containing a great excess of carbon and hydrogen, and are devoid of nitrogen. Since they do not exist in the blood, they must be formed from it by cell action or in some other way. It will be remembered that the walls of the convoluted tubes are lined with spheroidal secreting cells, which are freely nourished by the blood brought from the Malpighian capsule through the efferent vessel. It is the function of these cells to separate from the blood certain substances, which are appropriated by them, and converted into the extractive material of the urine.

The convoluted portions of the uriniferous tubes are analogous, both in their structure and function, to the sebaceous glands of the skin, which also separate their oily secretion from the blood by cell action. The method of action of the skin and kidneys, therefore, is identical, except that in the skin the two systems of glands are separated, while in the kidney they are united, forming the convoluted tube. The straight portion of the tube merely conducts the fluid secreted by the Malpighian tuft and tube into the pelvis of the kidney, and thence into the ureter and bladder.

The separation of the urinary secretion is continuous, and not intermittent, as might be supposed. The tufts and cells are never at rest from the day of birth until death. If any thing occurs to interfere with their action, it is immediately shown by the blood-poisoning which takes place, the urea and extractive accumulating in the system, and producing coma, which rapidly proves fatal unless it is relieved.

The action and function of the kidney may be briefly summed up as follows: The renal artery delivers to the organ im-

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How and by what mechanism are they separated? How and where is the extractive separated? What glands of the skin are analogous to the convoluted tubes? Is the secretion of urine continuous or intermittent? What is the effect of a non-secretion of urine? Explain the action of the kidney.

pure blood, laden with urea and other deleterious ingredients. It gradually subdivides, until finally small arteries are formed, called the afferent vessels; these enter the capsule at the termination of the uriniferous tube, and, dividing into capillaries, form the Malpighian tuft, which separates the water, salts, and nitrogenized constituents of the secretion.

From the Malpighian capsule the blood is brought by the efferent vein, which passes to the walls of the convoluted tubes to form a capillary system that nourishes the spheroid cells, by which the extractive is secreted. In this capillary system the twigs of the renal vein originate, and the blood is returned in a purified condition to the vena cava ascendens. The aqueous fluid, with its dissolved salts, that was filtered through the Malpighian tuft, passing into the convoluted tube, washes the extractive into the pelvis of the kidney, and thence to the bladder, where the urine is retained, until the distention of the organ and the pain produced induces us to empty it.

LECTURE XXVI.

THE URINARY SECRETION.

Rapidity of Excretion of deleterious Substances by the Kidneys.—Experiments on the Origin of Urea.—Effect of Diet and Exercise on the Amount of Urea excreted by the Kidneys.

THE rapidity with which deleterious substances are conveyed out of the system is shown by the fact that if a dose of iodide of potassium is taken, it may be found, by suitable tests, in the urine passed ten minutes afterward. Not only are salts quickly removed from the system by the kidneys, but organic substances are also rapidly eliminated, for we are all acquainted with the peculiar disagreeable odor which one of the constituents of asparagus gives to the urine passed immediately after eating that vegetable.

Urea is the most important of the constituents of the urine as regards quantity, forming nearly one half of the total solid residue; it has therefore been the subject of special examination, many supposing that it represents the disintegration of muscular tissue.

What is the function of the bladder? Give some examples illustrative of the rapidity with which deleterious substances are excreted by the kidneys. What opinions are held regarding the origin of urea?

In my thesis for the degree of Doctor of Medicine, published in the New York *Journal of Medicine* for February, 1856, it is shown that in all probability urea merely represents the excess of nitrogenized material consumed; I therefore introduce it in support of that opinion.

Is the Urea in Urine due to Muscular Motion?—The first step in the solution of such an inquiry as the above is the choice of some reliable process by which analyses determining the amount of urea in various samples of urine may be made.

The process employed in the following experiments consists essentially in the decomposition of the urea by nitroso-nitric acid, and then determining the carbonic acid produced by means of hydrate of baryta.

Next we have to settle upon some standard with which the results obtained in our experiments may be compared. The one chosen as being the most convenient is the total quantity of urea passed in twenty-four hours, a very small amount of exercise being taken; the diet being mixed, and as nearly as possible the same in amount each day.

The analyses given in the following table fulfill these conditions, and, with the exception of the eleventh, twelfth, and thirteenth, were all obtained from the same individual. In addition to the urea, the solid residue, that is, the solid material left after the evaporation of the water contained in the excretion, was also determined.

Average daily amount of motion, 3 miles.			
Analysis.	Urine.	Solid Residue.	Urea.
	In Grammes.	In Grammes.	In Grammes.
1	754·000	44·488	23·649
2	1227·000	52·768	26·030
3	1153·000	54·202	26·034
4	1042·000	60·456	31·902
5	1160·000	60·825	31·008
6	990·000	56·493	27·567
7	1737·000	66·874	31·062
8	1042·000	53·943	26·551
9	997·000	55·288	27·616
10	1079·000	54·513	23·873
11	871·000	55·598	25·271
12	775·000	51·440	27·323
13	743·000	51·023	26·816
14	974·000	52·718	24·476
15	1462·000	59·838	28·424
16	768·000	50·120	24·394
17	1595·000	62·096	29·232
18	1536·000	57·838	28·621
Total for 18 days,	19905·000	1000·521	489·849
Mean for 24 hours,	1106·	55·584	27·213

What is the average amount of urine, solid matter, and urea excreted in a day?

If we compare the urea with the solid residue in the manner proposed by Dr. Simon, the result of these analyses is the same as of those given by Berzelius, Lehmann, and others.

1000 Parts of Solid Residue contain, according to

Berzelius .... 451· of Urea.
Lehmann .... 490· " "
Marchand .... 492· " "
Above Analyses .... 490· " "

Our standard, therefore, is as follows, in grammes:

Urine.	Solid Residue.	Urea.	1000 of S. R. contain of Urea
1106·	55·584	27·213	490·

We may now proceed to determine, 1st. The daily quantity of urea excreted in absolute rest; 2d. That during violent and sudden muscular action.

The Amount in Absolute Rest.—In order to obtain this, I analyzed the urine of the patient whose history is given below.

C. Marshall, aged 22, a Virginian by birth, had his leg broken by an accident on the Panama Railroad as he was returning home; ten days after the accident he entered the New York Hospital, where he was treated. Nothing unusual occurred, and at the expiration of eight weeks he was discharged, cured. Diet was mixed, being the usual hospital allowance.

The following samples of urine were obtained after three weeks of confinement, and therefore represent the urine of absolute rest.

Analysis.	Urine.	Solid Residue.	Urea.
	In Grammes.	In Grammes.	In Grammes.
19	871·	55·598	25·271
20	775·	51·440	27·323
21	743·	51·023	26·816
Total for 3 days,	2389·	158·061	79·410
Mean for 24 hours,	796·	52·687	26·470
1000 of Solid Residue contain 502 parts of Urea.			

Comparing these results with our standard, we obtain the following table:

	Total Urine.	Solid Residue.	Urea.	1000 of S. R. contain of Urea
Standard	1106·	55·584	27·213	490·
Absolute Rest ...	796·	52·687	26·470	502·

From this we see that there is a small diminution in the to-

What is the effect of absolute rest on the formation of urea?

tal quantity of solid residue and urea excreted in a state of absolute rest, but the solid residue is richer in urea.

The Amount of Urea excreted in violent Muscular Action.—For the purpose of determining this, I walked at different times a distance of thirteen miles on a level causeway, the greater portion being performed at the rate of four and a half miles an hour, the pulse in each trial rising to above one hundred. Diet same as in the standard.

Average daily amount of motion, 13 miles.			
Analysis.	Total Urine.	Solid Residue.	Urea.
22	1042·	53·943	26·551
23	768·	50·120	24·394
Total for 2 days,	1810·	104·063	50·945
Mean for 24 hours,	905·	52·031	25·472
1000 of Solid Residue contain 489· parts of Urea.			

Comparing this with our standard, we obtain the following table:

	Urine.	Solid Residue.	Urea.	1000 of S. R. contain of Urea
Standard...........	1106·	55·584	27·213	490·
Violent Motion...	905·	52·031	25·472	489·

which demonstrates that when sudden and violent exercise is taken, the total amounts of solid residue and urea are diminished, while the proportion of urea to solid residue remains about the same.

Now if the urea in urine was altogether the product of muscular disintegration, the conditions which prevailed in experiments 22 and 23 would have greatly increased its amount; but, instead of this, we find that in the same individual, and under otherwise the same circumstances, violent muscular action does not increase the total quantity of urea passed in a day.

Again, in a state of absolute rest, if the urea was owing mainly to the disintegration of tissue from exertion, we should expect to find a comparatively small amount of that substance present, and this quantity would represent the destruction of the muscular tissue engaged in carrying on the process of organic life. But, instead of this, we find from experiments 19, 20, and 21, that in rest as perfect as can be obtained there is no great diminution in the total quantity of urea excreted, and that the solid residue left after the evaporation of the water is actually richer in urea.

We therefore conclude that violent and brief muscular action

What is the effect of violent muscular action ?

does not exercise any great influence on the urea in urine. Nor is it probable that that substance has passed out of the system through the skin as an ingredient of the sweat. It is also equally improbable that it has escaped by way of the intestinal canal, for urea is not a normal ingredient of fæcal matter, except when the kidneys are exsected, or their function is in some way disturbed. But we are supposing that an excess of urea has been formed, and the reason we give for this supposition is, that if such violent action were continued for a great length of time, the muscular structures would greatly decrease in weight. And as urea contains a large quantity of nitrogen, which is also a characteristic component of muscle, we therefore say that urea represents the disintegration of muscle. But may it not be that the nitrogen contained in the destroyed tissue has escaped directly through the lungs, without entering into composition with other substances? This is not at all improbable, for the experiments of MM. Regnault and Reiset on respiration have shown that warm-blooded animals, under the usual circumstances in which they exist, excrete by means of their lungs an amount of nitrogen equivalent to from $\frac{1}{100}$ to $\frac{1}{50}$ of the oxygen consumed.

It has been supposed, from the experiments of Dr. Simon, that violent exercise increased the amount of urea; but if we examine his analyses as they are given in his "Chemistry of Man," it will be seen that as the amount of urine is not given, we have no means of knowing whether the total quantity of urea was increased or not. Indeed, it is more probable that the apparent increase is owing to the loss of water by evaporation. The same objection is to be urged against the analyses of Dr. Percy.

Lehmann gives in his work two experiments on the influence of exercise on the quantity of urea. In these, severe bodily exercise increased the amount from thirty-two grammes to thirty-six in twenty-four hours on one occasion, and to thirty-seven on another. It is true that in this case we have an increase, but it is not more than analyses made from day to day would show.

We therefore conclude, from the experiments thus far made, that sudden and violent exercise does not increase, to any extent, the amount of urea in urine.

As it is evident that exercise does not exert any material influence on the fluctuations of urea, we must seek for other causes, and among these is diet, which has been shown, by the

experiments of Lehmann, to exert a most notable influence, as may be seen in the following table:

	Total Urine.	Solid Residue.	Urea.
Animal Diet	1202·	87·44	53·198
Mixed "	1057·	67·82	32·489
Vegetable "	909·	59·23	22·481
Non-nitrogenized "	——	41·68	15·410

From this we observe that in animal diet there are nearly four times as much urea excreted as in a non-nitrogenized one; and if we compare it with the solid residue, we find that in a non-nitrogenized diet the solid residue contains far less urea than in an animal one.

Comparing these results with those obtained from the experiments given on exercise, we see how great the influence of diet is, and hence we should be led to suppose that there must be a considerable difference in the amount of urea excreted during the day, compared with that excreted in the night. Accordingly, we come to the second inquiry, viz., What are the semi-diurnal variations, and what is the influence of rest and motion on them?

Average daily amount of motion, 13 miles.						
	Night Urine.			Day Urine.		
Anal.	Urine.	Solid Residue.	Urea.	Urine.	Solid Residue.	Urea.
27	...	......	......	678·	35·802	17·448
28	479·	25·023	13·560	...	......	......
29	...	......	......	442·	26·406	11·985
30	547·	30·087	15·582	...	......	......
31	...	......	......	627·	31·618	14·112
32	413·	22·325	12·439	...	......	......
33	...	......	......	473·	26·022	10·464
34	606·	28·491	13·409	...	......	......
35	...	......	......	561·	33·709	14·216
36	310·	21·889	11·055	...	......	......
37	...	......	......	413·	26·809	14·426
38	362·	24·631	12·897	...	......	......
39	...	......	......	443·	31·492	16·800
40	300·	19·531	10·016	...	......	......
41	...	......	......	354·	22·000	11·612
42	620·	30·718	12·864	...	......	......
43	...	......	......	516·	30·505	13·371
44	946·	29·333	15·053	...	......	......
45	...	......	......	502·	30·161	13·709
46	266·	19·959	10·685	...	......	......
47	...	......	......	620·	34·774	14·912
48	975·	27·322	14·320	...	......	......
49	...	......	......	916·	33·000	15·694
50	620·	24·833	12·927	...	......	......
Total	6444·	304·142	154·807	6545·	362·298	168·749
Mean	537·	25·345	12·900	545·	30·191	14·062
1000 of Solid Residue contain 509· parts of Urea.				1000 of Solid Residue contain 466· parts of Urea.		
Difference between the percentage of Urea in the Solid Residue of the day and night, 43· in 1000.						

What is the effect of diet on the amount of urea?

Of the Semi-diurnal Variations.—These have not as yet been noticed by any one who has experimented with urine. They are very marked and uniform in their occurrence, and much more apparent than the fluctuations caused by exercise. In order to show them, the preceding analyses of urine which was passed during the day, compared with those of the urine voided in the subsequent night, are given. The day was reckoned from 7 A.M. to 7 P.M., when the night period began.

Diet in these experiments was mixed, and about the same in quantity each day. A moderate amount of exercise was taken.

These analyses demonstrate that the total amounts of solid residue and urea passed in the course of the day are much greater than those voided during the night, while the solid residue of the urine excreted in the night is richer in urea than that of the day.

These results are doubtless owing to the influence of diet; for, during the day, food having been ingested, the elimination of the excess begins to take place almost immediately, thus producing an increase in the amount of urea; while during the night, though the total quantity of urea excreted is less, yet it forms a larger portion of the solid residue. This may be attributed to the fact that in the day a greater amount of phosphates and sulphates being formed, these, with the chlorides and other salts taken in at the same time, diminish the proportion of urea to solid residue.

If this explanation is the true one, we should expect to find that in absolute rest the amount of sulphates, etc., being less, the difference between the percentage of urea in the solid residue of the day, compared with that of the night, would also be less. But if violent muscular action was undergone, these differences should become greater on account of the increase of the amount of sulphates, etc.

In order to demonstrate that this is so, the following analyses are given.

The Influence of Rest on Semi-diurnal Variations.—For the solution of this problem, the urine of the patient Marshall, whose history is given above, was used. Analyses of the urine of three days were made.

What do the semi-diurnal variations show?

Night Urine.				Day Urine.		
Anal.	Urine.	Solid Residue.	Urea.	Urine.	Solid Residue.	Urea.
51	...	......	......	561·	33·709	14·216
52	310·	21·889	11·055	...	......	......
53	...	......	......	413·	26·809	14·426
54	362·	24·631	12·897	...	......	......
55	...	......	......	443·	31·492	16·800
56	300·	19·531	10·016	...	......	......
Total	972·	66·051	33·968	1417·	92·010	45·442
Mean	317·	22·017	11·322	472·	30·670	15·147
1000 of Solid Residue contain 514· parts of Urea.				1000 of Solid Residue contain 493· parts of Urea.		
Difference between the percentage of Urea in the Solid Residue of the day and night, 21· parts in 1000.						

From this we see, that in absolute rest the difference between the percentage of urea in the solid residue of the day compared with that of the night is only twenty-one parts in one thousand, while, when a small amount of exercise is taken, it is forty-three parts in one thousand; this is what we should have expected to find if the explanation we have given of this variation was the true one.

The Influence of Violent Exercise on the Semi-diurnal Variations.—On the days on which these samples of urine were passed, the same amount of exercise was taken as in the former experiments on violent muscular action.

Average daily amount of motion, 13 miles.						
Night Urine.				Day Urine.		
Anal.	Urine.	Solid Residue.	Urea.	Urine.	Solid Residue.	Urea.
57	...	......	......	627·	31·618	14·112
58	413·	22·325	12·439	...	......	......
59	...	......	......	502·	30·161	13·709
60	266·	19·959	10·685	...	......	......
Total	679·	42·284	23·124	1129·	61·779	27·821
Mean	239·	21·142	11·562	564·	30·889	13·910
1000 of Solid Residue contain 546· parts of Urea.				1000 of Solid Residue contain 450· parts of Urea.		
Difference between the percentage of Urea in the Solid Residue of the day and night, 96· parts in 1000.						

On examining the result of these analyses, we find that the difference of the percentage of urea in solid residue is as much as ninety-six parts in one thousand, thus giving additional proof that our supposition concerning the cause of these variations is the true one; and by comparing them together, we obtain a table which is almost an index of the amount of exertion undergone.

Table of apparent Variations of percentage of Urea in Solid Residue of day and night in different degrees of Motion.

Absolute Rest	21 parts in 1000
Moderate exercise	43 " " "
Violent "	96 " " "

The only other cause to which these fluctuations could be

What is the effect of exercise on the semi-diurnal variations?

attributed would be variations in the amount of urea itself. Now, if this was the case, there would be more urea excreted in the night than in the day. But if we examine the following table we find the opposite condition holds.

Table of Variations of total Amount of Urea passed in the day and in the night during different degrees of Exercise.		
	Day Urea.	Night Urea.
Absolute Rest	15·147	11·332
Moderate Exercise	14·062	12·900
Violent "	13·910	11·562

We therefore conclude that the fluctuations of the percentage of urea in the solid residue of the day compared with that of the night are due to the excretion of the phosphates resulting from mental action, and to the sulphates formed during muscular activity.

We have also supposed that the cause of the increase of the total amount of urea during the day was due to the ingestion of food. In support of this, we give the following analyses:

In these, the twenty-four hours are divided into five periods. The first four consist of four hours each, and extend from 6 30 A.M. to 10 30 P.M.; while the fifth is eight hours long, and extends from 10 30 P.M. to 6 30 A.M. As regards the time at which meals were taken—breakfast, a light meal, at 7 A.M.; dinner, constituting the main meal, at 3 P.M.; and tea at 7 P.M. A moderate amount of exercise was taken in the morning.

First Period, from 6 30 A.M. to 10 30 A.M.			
Analysis.	Total Urine.	Solid Residue.	Urea.
61	221·	11·754	5·963
62	162·	9·270	4·312
63	177·	8·516	3·763
64	177·	10·468	5·000
Total	737·	40·008	19·038
Mean	184·	10·002	4·759
1000 of Solid Residue contain 475 parts of Urea.			

Second Period, from 10 30 A.M to 2 30 P.M.			
Analysis.	Total Urine.	Solid Residue.	Urea.
65	280·	12·782	6·001
66	147·	7·688	3·338
67	236·	10·882	4·552
68	147·	8·427	4·188
Total	810·	9·779	18·079
Mean	202·	9·945	4·519
1000 of Solid Residue contain 454 parts of Urea.			

Third Period, from 2 30 P.M. to 6 30 P.M.			
Analysis.	Total Urine.	Solid Residue.	Urea.
69	177·	11·266	5·484
70	133·	9·448	4·335
71	214·	12·220	5·797
Total	524·	32·934	15·616
Mean	175·	10·978	5·205
1000 of Solid Residue contain 473 parts of Urea.			

Fourth Period, from 6 30 P.M. to 10 30 P.M.			
Analysis.	Total Urine.	Solid Residue.	Urea.
72	184·	10·534	5·629
73	192·	10·571	5·417
Total	376·	21·105	11·046
Mean	188·	10·552	5·523
1000 of Solid Residue contain 523 parts of Urea.			

Fifth Period, from 10 30 P.M. to 6 30 A.M.			
Analysis.	Total Urine.	Solid Residue.	Urea.
74	295·	14·489	7·931
75	221·	11·754	7·022
76	340·	13·772	8·347
Total	856·	40·015	23·300
Mean	285·	13·338	7·766
1000 of Solid Residue contain 582 parts of Urea.			

If we collect together the results furnished by these analyses, we obtain the following table:

	Period.	No. of Hours.	Total Urine.	Solid Residue.	Urea.	1000 Solid Residue contain of Urea
1	From 6 30 to 10 30	4	184·	10·002	4·759	475·
2	" 10 30 " 2 30	4	202·	9·945	4·519	454·
3	" 2 30 " 6 30	4	175·	10·978	5·205	473·
4	" 6 30 " 10 30	4	188·	10·552	5·523	523·
5	" 10 30 " 6 30	8	285·	13·338	7·766	582·

From this table we find that the period of the day at which the greatest amount of urea is excreted begins about dinner, and continues for a time after tea. The period at which the next greatest amount is excreted is just after breakfast, while during the eight night hours far less is excreted than during the same time in the afternoon.

We therefore conclude that, as the ingestion of food can exercise so rapid and marked an influence on the quantity of urea, it is the cause of the increased excretion of that substance during the day.

Reviewing the results arrived at, we conclude finally:

CONCLUSIONS.

1. Exercise does not increase to any extent the amount of urea in urine.

2. The ingestion of food during the day causes a greater amount of urea to be excreted at that time than is excreted during the night.

LECTURE XXVII.

EXAMINATION OF URINE.

Methods for determining the Specific Gravity and Reaction of Urine.—Tests for an Excess of Urea.—Uric Acid.—Sulphates and Phosphates.—Tests for Albumen.—Origin of Albuminous Urine.—Tests for Blood in Urine.—Tests for Bile.—Pettenkofer's and Heller's Tests.—Diabetic Urine.—Moore's and Trommer's Tests for Sugar.—Maumini's Test.—The Fermentation Test.—Detection of Pus.

SINCE urine is one of the chief channels by which effete materials are voided from the system, it becomes a matter of great interest, especially to physicians and invalids, to know the methods by which we may determine any improper increase in the ordinary ingredients of the secretion, or detect the appearance of new and abnormal substances.

Fig. 114.

The first step in the examination of a sample of urine is to notice its *color* and the *quantity* passed. The *specific gravity* should then be determined. This is done by means of a small instrument called the urinometer, *Fig.* 114. It is an ordinary areometer, adapted to the examination of urine, and indicating specific gravities from 1000 to 1060, within which limits the specific gravity of the urine generally falls, that of normal urine being from 1020 to 1030.

In using this instrument, the liquid should be poured into the cylinder without making a foam. This may be accomplished by holding the jar in an inclined position, at an angle of about 45°; the fluid will then run down the side without making any froth, if it is poured in gently. If the specific gravity of the sample is above 1040, we may suspect the presence of sugar; but excess of urea will give a similar result. If it is very low, and continues so for many days, the urine probably contains albumen.

The *reaction* is determined by the use of litmus paper, which may be bought at the apothecaries', or at a chemical furnishing

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How is the specific gravity determined? What is the specific gravity of healthy urine? What is the urinometer? How is the formation of a foam to be avoided? How is the reaction determined?

store. Blue and red paper should be provided. The test is performed by dropping portions of paper of both colors into the liquid; if they are red, it is acid; if they are both blue, it is alkaline; if one is red and the other blue, it is neutral.

When voided, healthy urine is nearly always acid; but in a short time, depending on the temperature, it commences to decompose, ammonia being formed, and the reaction becoming alkaline. When the urine is highly alkaline at the time it is voided, and especially if it has a putrid or ammoniacal odor, there is some irritation or inflammation in one of the divisions of the urinary apparatus, generally the bladder, that causes an increase in the amount of mucus, which promotes the decomposition of the urine to such an extent that it commences while it is yet in the bladder.

The constituents of healthy urine that are increased by disease are, Urea. The ordinary amount of this ingredient is about 30 parts in 1000. As long as it is present in proper proportion, the specific gravity of the secretion is below 1030; but if it increases in quantity, the specific gravity rises, and the urine, on the addition of nitric acid, forms crystals of nitrate of urea at a temperature of 60°. A strong solution of oxalic acid will produce, under the same conditions, crystals of oxalate of urea, if the mixture is kept in a cool place.

An excess of uric acid is usually accompanied by a high color. After a short time, a crystalline precipitate, commonly called the brick-dust deposit, is formed: it is in part produced by the urine cooling, and in part by its decomposition. The deposit rarely consists of pure uric acid, but contains in addition urate of ammonia and urate of soda, together with coloring matter.

Uric acid may be obtained, for the purpose of examination and study, by adding to a pint of urine about half an ounce of hydrochloric acid, and setting the mixture aside for twenty-four hours or longer. By this method large crystals of uric acid of a reddish color may be procured in any desired quantity, by employing a sufficient amount of urine.

Placing some of the crystals obtained in the above manner on a slip of platinum foil, and raising them to a red heat, they undergo oxidation, and an odor similar to that produced by

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What is the reaction of freshly-passed urine? Why does it become alkaline? In what disease does it turn alkaline in the bladder? What is the ordinary proportion of urea in urine? How may an excess of urea be detected? What change does an excess of uric acid impress on the color of urine? In what forms may uric acid be present in urinary deposits? How may uric acid be prepared from urine? What is the odor given by burning uric acid?

burning hair is evolved. If the crystals have been produced in the natural manner, *i. e.*, by the gradual decomposition of the urine, a large amount of residue will remain on the foil, which is composed chiefly of phosphates of lime and soda, with a trace of sulphates.

The most reliable chemical test for the presence of uric acid is the murexide test. It is performed by placing a few crystals in a watch-glass, or other small dish, adding a little strong colorless nitric acid, and evaporating carefully to dryness. A yellow residue remains, to which dilute ammonia is to be added. A beautiful reddish-purple color is immediately produced, to which the name of murexide is given.

The phosphates are often present in such excess as to form a copious deposit soon after the urine is passed. If the urine is heated before the sediment forms, a cloudy precipitate is produced, which is readily dissolved by the addition of a few drops of nitric acid. The deposit of phosphate may be distinguished from urate of ammonia by the fact that if it is warmed with some of the urine in a test tube, the urate dissolves, while the phosphate remains undissolved. It often happens that urate and phosphate are both present in excess; when this is the case, the murkiness caused by the precipitated urate dissolves on the first application of the heat, the liquid becoming clear, and remaining so for a few seconds; it then becomes turbid again, owing to the precipitation of the phosphates by the continued heat. From deposits of uric acid those of phosphates may be distinguished by the addition of a few drops of nitric acid, the phosphates or urates being immediately dissolved, but uric acid remaining untouched by the dilute acid that is formed, though it readily dissolves in pure, strong acid.

The sulphates are not often made the subject of examination, but they may be readily determined by acidulating a measured quantity of urine with an excess of hydrochloric acid, and then adding from a burette a graduated solution of chloride of barium. When the test ceases to produce a precipitate, the quantity that has been used is read off on the scale, and from the result obtained the amount of sulphates in the sample can be calculated. For a more extended explanation of such volumetric processes the reader is referred to chemical works.

Describe the murexide test. What is the effect of heat on samples of urine containing an excess of phosphates? How does phosphatic urine act with nitric acid? How may a deposit of phosphates be distinguished from one of urate of ammonia? How may a deposit of phosphates be distinguished from one of uric acid? How may an excess of sulphates be detected?

The chlorides are said to be affected in pneumonia. They may be determined by acidifying with a considerable excess of nitric acid, and then adding a graduated solution of nitrate of silver, as in the preceding example. From the quantity of silver solution used, the amount of chlorides present may be estimated.

From variations in the normal constituents of the urine, we now pass to the consideration of the abnormal substances which from time to time appear in the secretion; among these, the chief are albumen, bile, blood, chyle, and sugar.

Urine containing albumen usually has a specific gravity below 1025; sometimes it falls to 1004. This is by no means uniform, for I have often examined specimens which had a specific gravity higher than 1030, and yet they were laden with albumen.

Albuminous urine is also usually light colored, but this is by no means a reliable distinction. The tests by which albumen may be detected are,

1st. Heat. Place in a test tube some of the suspected urine, and raise its temperature. Before the boiling point is reached a cloudy precipitate forms, which might be mistaken for phosphates, but may readily be distinguished from it by the addition of a few drops of nitric acid, which dissolves the phosphates, but leaves the coagulated albumen untouched. If the urine is highly alkaline, heat will often fail to give a precipitate, if the quantity of albumen is small; under these circumstances, the liquid must be acidified before heat is applied.

2d. Nitric acid. Add to some urine in a test tube a few drops of nitric acid; the albumen present is immediately precipitated in a cloudy form. Other bodies will also produce a precipitate with nitric acid. If there is a large excess of uric acid or urates, they will form a precipitate of minute crystals of uric acid, or nitrate of urea, which is easily mistaken for the albuminous cloud. If the patient is taking cubebs or copaiba for disease of the urinary apparatus, a similar precipitate is formed by the addition of nitric acid, which arises by its producing an insoluble compound with certain principles contained in those medicines.

How may an excess of chlorides be detected? Mention some of the abnormal substances found in urine. What is the effect of the presence of albumen on the specific gravity of urine? Does albuminous urine always possess a low specific gravity? What is the color of albuminous urine? What are the tests for albumen? How may the albumen precipitate by heat be distinguished from the phosphate precipitate? Will heat give a precipitate in highly alkaline urine that is albuminous? Under what circumstances will the nitric acid test for albumen lead to error?

3d. Bichloride of mercury, tannin, and a number of other substances produce precipitates with albumen; but the tests in ordinary use are nitric acid and heat, which answer all required purposes, if they are employed with judgment.

Albumen sometimes appears in the urine for a short time when the diet has contained a superabundance of that substance. In the exanthemata, especially in scarlet fever, it appears for a time. The urine of pregnant women also at times contains albumen. With these exceptions, its presence is always to be regarded as a symptom of more or less serious disease of the kidney, in which the spheroidal cells of the convoluted tubes and the Malpighian tuft are involved. It doubtless often commences as an acute disease, and recovery is possible; but in the great majority of instances the organs mentioned undergo structural change, the spheroidal epithelium of many of the tubes being destroyed, and the kidney finally undergoing granular or fatty degeneration. So common is disease of the kidney among the lower classes, that out of nearly 500 post-mortems I witnessed or made in Bellevue Hospital during my term of service in that institution, I only saw perfectly healthy kidneys in two adult subjects.

Albumen may be present because the urine contains blood, bile, or chyle; but we shall treat of such cases when considering those abnormal ingredients.

Blood in urine may be derived from the bladder, ureter, or kidney. When it has come from the bladder or ureter it usually forms clots of greater or less size, depending on the rapidity with which it has been poured out. When it is derived from the kidney it rarely forms a clot, but gives to the urine a uniform reddish or brown color. When a sufficient period has elapsed it forms a deposit, which, under the microscope, is found to be composed of blood discs.

When urine containing blood is heated in a test tube, the albumen of the blood, as it coagulates, entraps the discs, which give to the precipitate formed a brown tint, that distinguishes it from the white cloud produced when the urine contains albumen only. Nitric acid also gives in bloody urine a dark-colored coagulum, that produced in albuminous urine being white.

' Under what circumstances does urine contain albumen temporarily? What is the state of the kidney when the albumen is always present? With what substances does albumen occur? From what sources may blood in the urine be derived? How may we distinguish between blood from the kidney and from other parts of the urinary apparatus? What is found in the deposit formed when it is examined under the microscope? How does urine containing blood act when it is heated? How does it act with nitric acid?

When the microscope fails to detect blood discs, as is the case in purpura, the presence of the dissolved corpuscles in the urine may be proved by evaporating a portion of the fluid to dryness, incinerating the residue, dissolving the ash in nitric acid, and applying the tests for iron. If it is found in considerable quantity, it is derived from the hæmatin of the dissolved discs.

In albuminous and bloody urine a sediment deposits, in which casts from the tubuli uriniferi may be found by a microscopic power of about 200. These casts are often almost colorless, and not easily seen in the fluid; at other times their surfaces are covered with kidney cells, with fatty and granular substances, or even blood discs. Their presence is a valuable indication of the state of the kidney, for they enable us to determine to what extent the disease of the organ has advanced, and to give an intelligent prognosis regarding the prospect of future recovery. Their absence is a favorable symptom, but their presence unfavorable, rendering great care on the part of the sufferer necessary in order to prolong life.

Urine containing *bile* usually has a yellowish or greenish-brown color. The tests by which this substance may be detected are, Pettenkofer's test, which is conducted in the following manner. The albumen is first separated by boiling the urine and collecting the coagulum formed on a filter; if the urine is alkaline, enough acid should be added to change its reaction, but no more. The filtered urine is then placed in a test tube, which should be immersed in a glass of cold water, so as to keep the mixture to be made in the tube at a low temperature. An amount of sulphuric acid equivalent to about two thirds the bulk of the urine employed should then be poured drop by drop into the tube; if it is added too rapidly, the temperature will rise too high and the test will fail. A small piece of white sugar is then dropped into the mixture, and the arrangement set aside. After the lapse of a sufficient period of time, depending upon the quantity of bile in the sample, a blood-red color commences to appear around the mass of sugar. If bile is not present, and the test is carefully conducted in the manner mentioned, the color is not obtained.

Heller's test is performed by adding to a portion of urine in

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How may the presence of blood in the urine be detected when the discs are dissolved, as in purpura? What are urinary casts? What indications of disease of the kidney do casts furnish? What is the color of urine containing bile? Describe Pettenkofer's test for bile. What precaution regarding temperature is to be observed in the use of Pettenkofer's test? Describe Heller's test.

a test tube a little albumen, mixing it well, and then precipitating the albumen with nitric acid. The coagulum formed presents a series of zones of different colors, red, blue, green, yellow. The same test may be applied by adding a drop of the acid to a few drops of the urine, placed on a white plate or saucer; at the line of meeting of the liquids a similar series of colors is seen. Stains of bile on clothing may be distinguished from pus stains by touching them with nitric acid: if it is bile, the colors are produced; if it is pus, they fail to appear.

The presence of *chyle* in urine gives to the fluid a peculiar milky color which is almost characteristic, but as it is sometimes absent or overcome by a stronger tint, it is often necessary to resort to chemical tests to detect its presence. In chylous urine albumen and fat co-exist; if the first is found, we may always suspect the presence of the second. Fat is easily detected by adding to some of the urine in a test tube about one half its bulk of sulphuric ether, and mixing them gently but thoroughly together. Allowing the mixture to rest for a few moments, the urine settles to the bottom of the tube, while the ether, containing in solution any fat that may have been present, floats on its surface.

The etherial solution is to be removed by a pipette, or by careful pouring into a clean watch-glass, perfectly free from all greasiness, and allowed to evaporate. If the urine contained fat, it remains on the watch-glass as a stain, formed of minute globules of oil, the nature of which may be readily proved by touching or rubbing them with the finger, when they impart to the glass a characteristic greasy mark.

Urine containing *sugar*, or *diabetic urine*, is usually light colored, and possesses a very high specific gravity, often reaching 1050 or even 1060. The methods for detecting the presence of sugar are, 1st. Moore's test, which consists in taking a portion of the urine in a test tube, adding about half its volume of liquor potassæ, and boiling the mixture; if a dark brown color is produced, the presence of sugar may be suspected.

2d. Trommer's test is performed by adding to some urine in a test tube two or three drops of solution of sulphate of cop-

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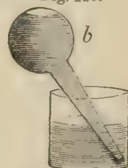
How may the presence of bile in stains on clothing be shown? What is the color of chylous urine? How is the presence of fat determined? What other ingredient does chylous urine contain? What is diabetic urine? What is its color and specific gravity? How is Moore's test performed? How is Trommer's test conducted?

per. An amount of liquor potassæ equal to the bulk of urine used is then poured in, and the mixture boiled. If diabetic sugar is present, the red suboxide of copper is precipitated; if there is no sugar, and a sufficient amount of liquor potassæ has been used, the black oxide of copper goes down. Care should be taken, in employing this test, not to use too great a proportion of sulphate of copper, for, if the quantity of sugar is small, it will not be detected, owing to the fact that the black oxide formed will completely obscure the red oxide.

3d. Maumini's test consists in preparing strips of white merino, by dipping them in a strong solution of bichloride of tin, and drying them in the water bath. A drop of urine is then placed on the strip, and it is warmed over a lamp; if the urine contains sugar, a black spot is formed.

4th. The fermentation test is the most reliable, for all the preceding tests are at times apt to fail, especially if the quantity of sugar is minute. It is performed by taking a bottle or flask, *b*, placing in it a teaspoonful of yeast, or more if the quantity of urine to be used is large; it is then nearly filled with the sample under examination, and well shaken, to diffuse the yeast throughout the mixture. The bottle is now completely filled with urine, and placed mouth downward in a large cup or other vessel containing sufficient fluid to prevent the liquid in the bottle flowing out.

Fig. 115.



Fermentation Test.

The apparatus is to be set aside for a day or so in a warm place; fermentation soon commences if sugar is present; carbonic acid gas being evolved, accumulates in the upper part of the bottle while alcohol is contained in the liquid.

The carbonic acid may be examined by decanting it into a smaller vessel, and agitating it with lime-water, when a precipitate of carbonate of lime is formed. The alcohol is usually detected without difficulty by its peculiar odor; but if the quantity of alcohol is small, and the amount of liquid large, it may be necessary to distill it, in order to be satisfied of its presence.

I have devoted some little space to the fermentation test, for it is only resorted to in doubtful cases; it should therefore be thoroughly understood.

Pus, when present, soon forms a sediment of pus corpuscles,

What precautions are to be observed in the use of Trommer's test? Describe Maumini's test. Describe the fermentation test. How is the presence of carbonic acid tested? What is the peculiarity of the pus deposit?

which are readily detected by the microscope. The deposit may be distinguished from that of mucus by the fact that when the bottle containing the urine is shaken, the precipitate diffuses equally throughout the liquid if it is pus, but forms rope-like, stringy masses if it is mucus. Usually the presence of pus is supposed to indicate inflammation of some portion of the urinary tract, but it is to be remembered that in females it may be derived from disease of the mouth or neck of the uterus or upper part of the vagina, attended by leucorrhœa. Whenever, therefore, a sample of urine is found to contain pus, an opinion should never be given until the sex of the patient is known.

The opposite tables will be found by students to be of great value in examining samples of urine in a rapid and satisfactory manner, since they present the subject in a condensed form, and enable them more quickly to appreciate the difference of action of all the ingredients of urine with a few simple tests.

LECTURE XXVIII.

THE LIVER AND SPLEEN.

Functions of the Liver.—Functions of the Spleen.—Relations of the Liver and Spleen to each other.

The peculiar province of the liver, until quite recent times, was supposed to be the separation of bile from the blood; but we now know that it has other and equally important functions to perform. While discussing the blood, it was stated that the fluid of the hepatic vein contained sugar, which did not exist in that of the hepatic artery or portal vein. In addition, therefore, to the separation of bile, this gland is also engaged in the conversion of fat into sugar, in which form the combustible is more readily oxidized. Another function performed by the liver is the production of a peculiar fat called cholesterine, which is appropriated by the nervous system as an exterior non-conducting covering to the nervous fibres, and is known as the white substance of Schwann.

The spleen belongs to the class of ductless glands, of which

How may a pus deposit be distinguished from mucus without a microscope? What precautions are to be taken in forming an opinion of the origin of a pus deposit in the urine of females? What was formerly supposed to be the sole function of the liver? What change is impressed on fat during its passage through the liver? What is cholesterine?

Examination of Liquid Urine.

	Color.	Reaction.	Specific Gravity.	Heat.	NO_5.	Other Tests.
Carbonate of Ammonia.	Varies.	Alkaline.	Varies.	....	Effervescence.	
Urea, excess of............	"	Varies.	High.	....	Crystals of nitrate.	Crystals with oxalic acid.
Sugar	"	"	"	....	....	Moore's and Trommer's—Fermentation.
Phosphates..................	"	"	Varies.	White precipitate.	....	Precipitate with heat; soluble in nitric acid.
Albumen	"	"	"	" "	White precipitate.	Bichloride of mercury, etc.
Bile..........................	Brown.	"	"	Often white precipitate.	Colored "	Pettenkofer's and Heller's.
Blood........................	"	"	"	Dark precipitate.	Dark "	Microscope and iron test.
Chyle...	White.	"	"	White "	White "	Separation of fat by ether.

Examination of Urinary Deposits.

	Color.	Heat.	(HCl).	(NO_5).	Other Tests and Remarks.
Urate of Ammonia...	White or light red.	Soluble.	Soluble.	Soluble in strong acid.	Reprecipitates when solution is cool.
Phosphates............	White.	Insoluble.	"	"	Reprecipitates by adding (NH_3); gelatinous.
Oxalate of Lime......	"	"	"	"	Reprecipitates by adding (NH_3); granular.
Uric Acid	Red.	"	Insoluble.	"	Murexide test.
Pus	Yellow.	"	"	Insoluble.	Deposit mixes on shaking the vessel; microscope.
Mucus	Cloudy.	"	"	"	Deposit does not mix.
Blood	Red.	"	"	"	Albumen in fluid; discs; microscope.
Cystine	White.	"	"	"	Soluble in (NH_3); deposits hexagonal plates on cooling.

NO_5=Nitric Acid. HCl=Hydrochloric Acid. NH_3=Ammonia.

the thyroid gland is another example. Its function was for a long time unknown, until finally Kolliker advanced the theory that it assisted in the destruction of the dying blood discs, forcing them to undergo dissolution, and converting their hæmatin into the substances which form the coloring matter of bile. In order to throw light on this subject, a series of experiments was undertaken, and printed by Professor Henry Draper in the New York *Journal of Medicine* for September, 1858. The method he employed was to take photographs of the blood from the splenic vein, and from vessels in other parts of the body, and, counting the proportion of perfect and imperfect discs in each, obtain accurate data from which the action of the spleen could be determined.

As the function of the spleen is of considerable importance, we quote from the paper in question freely, regarding it as proving beyond a doubt the truth of the views of Kolliker.

"The animal chosen was the frog (*Rana esculenta*). He is readily accessible, and the various kinds of blood can be obtained without much trouble by a careful dissection. His great advantage is the large size of his blood-cells, rendering it comparatively easy to see the changes occurring in them. The blood was photographed dry; 1st, because, from the result of several experiments, it did not seem to make any change either in the form or arrangement of the cells; and, 2d, to avoid the complications incident on the use of suspensory solutions.

"The plan of procedure was to take a frog and submit him to the operation of water at 150° Fahrenheit. This produces a species of tetanus suitable for the dissector's purpose, for all visible motion, except that of the heart, ceases. Then, the animal being stretched on a board and secured, a longitudinal incision was made at one side of the median line, to avoid the large vessels which lie in that line. The incision being carried through the abdominal walls, the intestines were carefully drawn out, and with them the spleen. A piece of white cardboard was then introduced underneath, in order to show plainly the course of the vessels.

"Up to this time it was not necessary to lose more than a single drop of blood in the dissection. The vessels being then plainly seen, the peritoneum was cut away, so that the spleen was retained in place only by them. The artery, being discerned, was seized by a pair of forceps, and cut on the side nearest the heart; then immediately after the veins were sev-

What was Kolliker's theory regarding the function of the spleen?

ered, and the spleen being put on a slip of glass, a drop of blood was allowed to spread itself thereon, the artery having all the while been retained closed. These drops were dried in the open air, and were submitted to a power of about 250 diameters, and photographed on glass.

"For the investigation of the functions of a gland, there is, of course, no plan so sure to be successful as an examination of the change it has induced in the fluid passing through it, and substantiating such an examination by an analysis of the produced secretion or excretion.

"In this gland, however, where no duct exists, and where the guidance of the secretion is lost, we are necessitated to examine the passing blood with double care, and, noting its changes, draw from them the requisite information.

"The essential object, then, of these experiments was to procure blood-cells from the splenic artery or other general systemic source, and also from the splenic vein. The blood from the artery or system generally represented, of course, blood as yet unchanged by the spleen, and that from the vein, blood at a maximum of change having just passed through that gland. A number of photographs of each kind were then taken, and one set compared with the other in various ways, and their differences noted. A choice was made at random from the tables of differences thus produced, and the conclusions at the end of this paper were drawn.

"At first, attention had to be directed to the relative anatomy of the splenic vessels of the frog. Injections of the arteries of his abdominal viscera are very difficult to make, because, as the vessels are small, a fine injection must be used, and the capillaries on the intestinal walls are so large, that, before all the arteries are full, some of the veins will be pretty well injected, and a dissection subsequent to the injection would be very deceptive. The only plan suitable under these circumstances is, after having drawn out the intestines and exposed the spleen on card-board, to inject and carefully observe how the vessels are filled. Of course, if in several cases one of those going to the spleen fills immediately, and the rest, after some time, begin gradually to be colored from the intestine toward the spleen, it is justifiable to say that the first filled is the artery, and the others the veins.

"The next point was to secure specimens from various frogs, and, having dried, to label them.

"The operation which succeeded, namely, photographing the

microscopic image, was by far the most difficult to perform successfully. It consisted of managing the microscope, of photographing the image on glass, and of transferring it by chloride of silver to paper. The method of illumination, and the focusing of the microscope, are only to be obtained by experience. In fact, these and the photography have left me but a small part of three summers. The difficulties of photography can only be known to those who have attempted it. A good negative is for long and long

"'Rara avis in terris, nigroque simillima cygno'

to the amateur.

"There will be presented in this paper results from the blood of the splenic veins of four different frogs, of the splenic artery of one, of the amputated legs of two, and of the vena cava of another batrachian, the toad; the four last being taken as general systemic blood.

"In a printed abstract, it is, of course, well-nigh impossible to introduce photographs for illustration, as was done in the original thesis, now deposited in the Archives of the University Medical College; and wood-cuts executed from those pictures would be worth nothing, for the value of photographs turns on the fact that they are produced (it might be said) without the intervention of human art, and are copies of microscopic images executed by the sun, not having passed through the draughtsman's and the engraver's hands, each of whom introduces in his work necessarily some inaccuracies, which are fatal to the comparative trial that these cuts would have to endure.

"We must therefore content ourselves with simply producing and examining the tables deduced from those photographs, referring any one who takes an interest in the matter to the originals.

"*In the blood of the splenic vein*, of 100 cells, 85 were distorted and broken, while only 14 were perfect. *The perfect were therefore to the imperfect as* 1 *to* 6. *In the blood of the amputated leg*, which is a fair representative of general systemic blood, of 140 cells, 68 were perfect, and 67 distorted and broken. *The perfect were to the imperfect as* 1 *to* 1. And what renders it more striking is, that of all the specimens of general blood that will be introduced, this one has the largest proportion of imperfect cells.

"In the following table, from which the above facts were

What is the proportion of perfect to imperfect cells in the blood of the splenic vein? How does it compare with the proportion in systemic blood?

drawn, the cells called perfect are those which are of an ecliptic shape, and whose nucleus is central.

TABLE I.

	Where from.	Perfect.	Distorted and broken.	Total.	Perfect to Imperfect.
Fig. 4	Splenic Vein......	14	85	100	1 to 6
Fig. 5	Amputated Leg ..	68	67	140	1 to 1

"It will be observed that the column marked Total does not correspond with the total of the two columns marked Perfect, and Distorted and Broken. This is owing to the fact that the three columns are produced by three separate countings from the photograph, and not by a process of addition and subtraction, as tables often are. The deficit consists of cells so nearly perfect, that in counting they are passed over as being neither perfect nor imperfect.

"The photograph corresponding to Fig. 4 contains besides two other interesting objects. The first is one of those bodies known as blood-corpuscle-holding cells, and consists of a sac whose section is about four times the size of that of an ordinary blood-cell, and which seems to contain in its substance four nuclei, each with a semi-developed or half disintegrated cell wall. It is the only one that has come under my notice at any time.

"The second object of interest is a blood-cell which apparently incloses a crystal; but, upon a very careful examination of the original preparation at different foci, this was demonstrated to be merely an optical deception, produced by a wrinkle in the cell wall.

"No note is taken of chyle corpuscles and free nuclei. There seems to be, as a general rule, from four to ten per cent. of them in all the kinds of blood that have been used for specimens in this thesis.

"Before going farther, it is well to create a standard of the perfect and imperfect cells in general systemic blood. By deductions from the following table, we shall show that *of every 5 cells of systemic blood,* 2 *are imperfect and* 3 *perfect.*

"This proportion seems extremely high for the distorted and broken cells. By leaving out Figure 5, we could lower it to 4 in 13; but it is better to allow it to remain, high as it is; for, although the imperfect may be, and probably are, considerably less in number, still, if we can establish the fact that average splenic blood (venous) contains a greater number of imperfect

cells than this, such a difference will be all the more striking when the average systemic proportion is lowered.

"The results that are now introduced are from pictures of blood procured from the amputated legs of another frog, from the splenic artery, and from the vena cava of an analogous batrachian, the toad.

TABLE II.

	Where from.	Perfect.	Distorted and broken.	Total.	Perfect to Imperfect.
Fig. 5	Amputated Leg.......	68	67	140	1 to 1
Fig. 6	Amputated Leg.......	73	56	137	4 to 3
Fig. 7	Splenic Artery.........	86	39	126	2 to 1
Fig. 8	Toad's Vena Cava....	68	5	73	13 to 1
	Total.................	295	167	476	3 to 2

"We shall now examine tables from several specimens of splenic venous blood, and from them shall demonstrate that *of every* 6 *cells from the splenic vein*, 5 *are imperfect.*

"The reason that so large a number as nine figures are used is because it is much more important to get a fair average proportion than in the former case; for any one can see systemic frog blood; not so with that from the splenic vein.

TABLE III.

	Perfect.	Distorted and broken.	Total.	Perfect to Imperfect.
Fig. 4	14	85	100	1 to 6
Fig. 9	15	82	97	1 to 5½
Fig. 10	17	101	120	1 to 6
Fig. 11	3	50	53	1 to 16
Fig. 12	10	67	81	1 to 6½
Fig. 13	13	103	120	1 to 8
Fig. 14	24	102	127	1 to 4
Fig. 15	23	74	97	1 to 3
Fig. 16	30	75	110	1 to 2½
Total........	149	739		1 to 5

"The photograph corresponding to Fig. 10 shows, as well as can be, all the characteristics of splenic venous blood. There are in it perfect cells, swollen cells, stretched cells, cells with a piece broken out, cells with a part of their contents removed, empty cells of a chlorotic appearance, broken cells with the nuclei near the edge, relics of cell walls, free nuclei. *Is the spleen creating or destroying?*

"Comparing now the results of Table II. with those of Table III., we see that in the former, of every 5 cells, 2 were imperfect, and in the latter, of every 6 cells, 5 were imperfect. Reducing to a percentage, we find of imperfect cells—in the systemic blood 40 per cent.; in splenic vein blood, 83 per cent.

"The conclusion, then, is plain. The number of imperfect

cells in splenic vein blood is double the general systemic average.

"We may also, by a careful examination, perceive that the progress of destruction is first a tendency to loss of form, then a decrease of the power of impeding light, caused either by change of color or diminution of the contained fluid, then a rupture of the cell wall, either from swelling or from some chemical change in it; finally, the escape of the nucleus, and complete solution of the cell wall. Not that this is always the case, for many cells seem to break down at once.

"But, let the change be what it may, it can only be partially accomplished in the spleen, else how is it that we see so many coming out distorted and decaying?

"The most natural conclusion is, that blood-cells coming here, after having made the tour of the circulation several times, have such a change wrought, either in themselves, directly or indirectly, by means of the plasma which contains them, that their walls become no longer capable of resisting the weak mechanical forces to which they are subjected. Perhaps the fibrinous wall changes like the fibrin of muscles, and becomes inosite and creatine; the inosite passing on to complete oxidation in the lungs with its kindred liver sugar, or becoming liver sugar. As for the rest of the cell, the fat of the nucleus becomes liver fat, or bile fat, or liver sugar, the hæmatin colors the bile, and the globulin becomes casein, or some analogous body.

"Some of those cells which have passed apparently safely through may perhaps carry the elements of change impressed upon them, and in this way we might account for the distortions in general blood.

"That such an action as I have described may take place in the cell wall in passing through the spleen is easy to believe from a very casual view of the structure of that organ.

"Finally, the great conclusion arrived at is, that as it is proved that the splenic vein blood contains at least double the general average of imperfect cells, *the spleen must be an organ for the disintegration of blood-cells.*"

Accepting the statement of Kolliker, that the function of the spleen is to destroy the old, almost worn-out discs, which can no longer perform in a proper manner the function of carrying oxygen, it becomes a matter of interest to examine the relations of the spleen and liver to each other.

In bile, the coloring matter is found to contain the iron that

entered into the composition of the hæmatin of the discs; in the spleen, discs are disintegrated and broken up. The relation of the organs to each other, therefore, seems to be, that the spleen destroys the discs, and the materials produced are filtered out from the blood by the liver, so that it becomes the duct of the spleen.

In review, we may sum up the functions of these glands as follows:

The spleen destroys discs.

The liver filters out the materials formed by the disintegration of discs.

It also converts fat into sugar, and produces cholesterine, which forms the non-conducting envelope of nerve fibre.

LECTURE XXIX.

THE NERVOUS SYSTEM.

Phosphorus the special Ingredient of Nervous Substance.—Production of Nervous Force.—Gray and white Nervous Substance.—The Ganglia described.—The Nerves described.—Divisions of the Nervous Mechanism.—The Nervous Systems of the Lower Animals.—The Sympathetic System.—The Cerebro-spinal System.—The Brain.—The Spinal Cord.—The Nerves.

Having completed the examination of the organs of locomotion, nutrition, and excretion, we now pass to the study of the nervous system, which regulates and controls their action. The peculiar element of nervous tissue is a phosphorized oil or fat, the amount of uncombined phosphorus in which determines in part its intellectual power, as is shown in the following table, in which the brain of an idiot contained about the same proportion of phosphorus as that of an infant, while the greatest proportion is found in that of the adult.

From L'Heretier.

	Brain of Infant.	Of Youth.	Of Adult.	Of Age.	Of Idiot.
Phosphorus......	8·	16·5	18·	10·	8·5

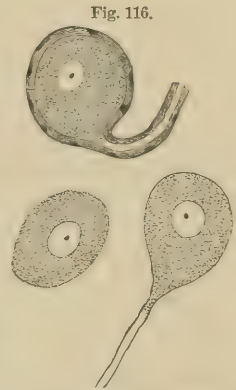
That nervous force is produced by the oxidation of phosphorus is demonstrated beyond discussion by the fact that any

What relation exists between the liver and the spleen? What are the functions of the liver? What is the function of the nervous tissue? What is the special component of nervous matter? How does the proportion of phosphorus in nervous substance vary with age? How is nervous force produced?

thing which implies or requires the development of nervous force, as continued muscular or mental action, or any powerful nervous affection, as grief or joy, is followed by an increase in the amount of the phosphates in the urine.

Of these facts any one may satisfy himself by resorting to the tests given in a previous lecture; such experiments, however, are not needed, for all persons must have noticed the enormous deposits of phosphates in the urine passed after hard study, or any severe mental excitement.

Fig. 116.

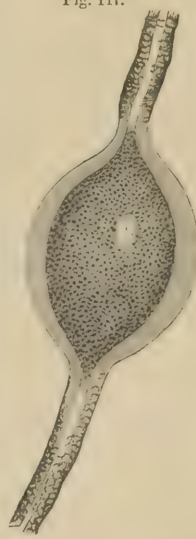


Nerve-cells, 350 Diameters.

In order to favor rapid oxidation, and the immediate removal of the phosphoric acid produced, all nervous tissues, but more especially those which originate the force, are freely supplied with arterial blood by an extensive and intricate system of capillary vessels.

Nervous tissues are composed of two kinds of materials: 1st. The gray or originating substance; 2d. The white or conducting substance. Gray nervous matter consists chiefly of cells, which may be regarded as being analogous to the cells of an ordinary Voltaic battery.

Fig. 117.



Bipolar Nerve-cell, 350 Diameters.

These cells vary in form, as is demonstrated by *Figs.* 116, 117, 118. In the first there is only a single pole to the cell; in the second there are two poles: such cells are therefore called bipolar cells; in the third there are many poles or projecting processes: such cells are consequently called multipolar. Though there is so great a variation in the figure and number of poles attached to nerve-cells, they are all constructed of the same materials, viz., an exterior envelope, which is filled with a granular substance, composed to a great extent of the phosphorized oil or fat previously mentioned.

In order to construct a nervous centre, a number of nerve-cells unite, their projecting

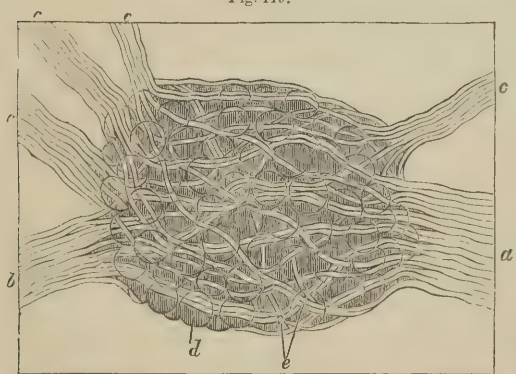
How is it proved that the oxidation of phosphorus originates nervous force? What is the function of gray and white nervous substance? What is the composition of the gray substance? To what part of an electrical apparatus are they analogous?

Fig. 118.

Multipolar Nerve-cell, 200 Diameters.

poles or fibres interlacing and intertwining to form a compound cell or ganglion, which is the counterpart of an electric battery. The ganglia are very numerous, being scattered all over the body, but the largest are found in the cranial cavity. Many of them seem to be endowed with special properties, but the greatest proportion are engaged in originating the nervous force, and controlling the rate of waste and repair, and in regulating the vigor of action of the various glands, organs, and tissues composing the system.

Fig. 119.



Ganglion of a Mouse.

In the figure, *d e* represents the nerve-cells and fibres which form the ganglion; *a b*, nerves communicating with other ganglia; *c c c*, branches that have originated in the ganglion.

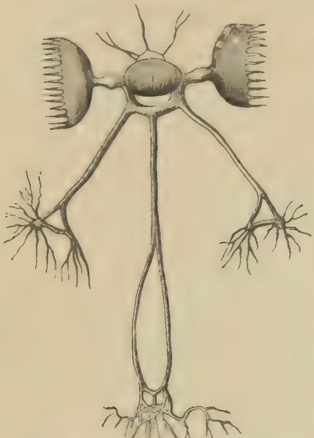
From the ganglia the nerves take their origin. They are composed of white nervous substance, arranged in the form of tubes, covered externally with a layer of cholesterine, which is a non-conductor, so that the nerve fibres resemble in their structure the wires of an electric combination, with their exterior non-conducting covering of silk.

The nervous mechanism in man and the higher animals consists of two portions, the sympathetic system and the cerebro-

How is a ganglion formed? What is the duty of a ganglion? Describe the structure of the nerves. What are the divisions of the nervous mechanism in man?

spinal axis. In the very lowest forms of animated creatures the sympathetic system alone exists.

Fig. 120.



Nervous System of Mollusca.

Fig. 121.

Nervous System of Radiata.

Fig. 122.

Nervous System of Articulata.

In molluscs the ganglia are scattered irregularly throughout the body of the animal; in radiates they are arranged in a circle around the mouth; in articulates they are placed along the median line, there being often a pair of ganglia for each ring composing the creature, and a single ganglion at each extremity of the nervous system.

Vertebrates possess a spinal cord and brain, which are protected throughout their whole extent by a covering of bone, and are frequently brought into communication with the sympathetic or ganglionic system, which is scattered throughout the body, its fibres entering into all the glands, being freely distributed to the muscular coats of the intestine, and forming a network on the arteries.

The conducting fibres of the sympathetic system are smaller than those of the cerebro-spinal axis; they also contain a number of nucleated cells.

In the following figure the distribution of the sympathetic nerve to the various organs is shown, together with some of the large ganglia connected with it: 1, the eye-ball; 2, branch of inferior oblique; 3, branches of tri-facial; 4, ophthalmic ganglion; 5, spheno-palatine; 6, otic; 7, submaxillary and, 8, sublingual ganglia; 9, ex motor oculi nerve; 10, facial; 11, glosso-pharyngeal; 12, right pneumogastric; 13, left pneumogastric; 14, spinal; 15, hypoglossal; 16, cervical plexus; 17, brachial

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What is the lowest form of nervous mechanism? How are the ganglia arranged in molluscs—in radiates—in articulates? Where is the sympathetic? Does it communicate with the cerebro-spinal system? What are the peculiarities of the fibres of the sympathetic?

Fig 123.

The Sympathetic System.

plexus; 18, intercostal nerves; 19, lumbar plexus; 20, sacral plexus; 21, superior cervical ganglion; 22, Jacobson's nerve; 23, carotid branch of vidian; 24, external motor oculi; 25, ophthalmic ganglion; 26, branch to pituitary body; 27, anastomosis of cervical ganglion with first cervical nerves; 28, carotid branches; 29, pharyngeal plexus; 30, laryngeal branch; 31, superior cardiac branch; 32, nerves of union of upper cervical with, 33, middle cervical ganglion; 34, anastomotic nerve; 35, recurrent; 36, middle cardiac; 37, junction of middle cervical and, 38, inferior cervical ganglia; 39, branches to great vessels; 40, branches to subclavian and vertebral arteries; 41, branch to first intercostal; 42, cardiac ganglion and its plexus; 43, 44, plexuses of right and left coronary arteries; from 45 to 46, thoracic ganglia; 47, the splanchnic; 48, semilunar ganglion; 49, lesser splanchnic; 50, solar plexus; 51, pneumogastric; 52, phrenic; 53, gastric coronary, 54, hepatic; 55, splenic; 56, superior mesenteric; 57, renal plexus; 58 to 58, lumbar ganglia; 59, lumbo-aortic plexus; 60, 61, enlargements of aortic plexus; 62, spermatic plexus; 63, inferior mesenteric plexus; 64, hypogastric plexus; 65 to 65, sacral ganglia; 66, coccygeal ganglion; A, heart, showing cardiac plexus; B, arch of aorta; C, innominata; D, subclavian; E, inferior thyroid; F, external carotid; G, internal carotid; H, thoracic aorta; I, abdominal aorta; J, primitive iliac; K, intercostals; L, pulmonary artery; M, vena cava descendens; N, vena cava ascendens; O, pulmo-

nary veins; *a*, lachrymal gland; *b*, sublingual; *c*, submaxillary gland; *d*, thyroid gland; *e*, trachea; *f*, œsophagus; *g*, stomach; *h*, small intestine; *i*, colon; *j*, sigmoid flexure; *k*, rectum; *l*, bladder; *m*, ureter; *n*, prostate gland; *o*, seminal vesicles; *p*, vas deferens; *q*, spermatic cord; *r*, diaphragm.

The sympathetic is the nerve of organic life. It takes charge of digestion, absorption, and circulation; regulates the rate at which the secretions of the glands are produced, and attends to the processes of nutrition, repair, and excretion. When the cerebro-spinal axis is at rest, the great sympathetic is busy repairing the wear and loss which the muscular and other tissues have undergone in the production of motion or action. It superintends the vegetative life of the animal, and is never at rest.

The cerebro-spinal system consists of the brain and the spinal cord and nerves; through it all the manifestations of animal life are originated and conveyed. It regulates the movements of the voluntary muscles, presides over the special senses, and furnishes the thought, ideas, and will, which have enabled man almost to annihilate time and space.

The brain is placed in the cranial cavity; its weight is equal to about $\frac{1}{36}$th of the total weight of the body. It is divided into two distinct portions, the cerebrum, or greater brain, which is above, and the cerebellum, or lesser brain, which lies beneath the posterior part of the cerebrum, as is shown in *Fig.* 124, in which 1 is the medulla oblongata; 2, pons varolii; 3, cerebellum; 4, pneumogastric lobule; 5, frontal convolutions; 6, parietal convolutions; 7, occipital convolutions; 8, fissure of Sylvius; 9, 9, its branches.

Fig. 124.

Exterior of Brain.

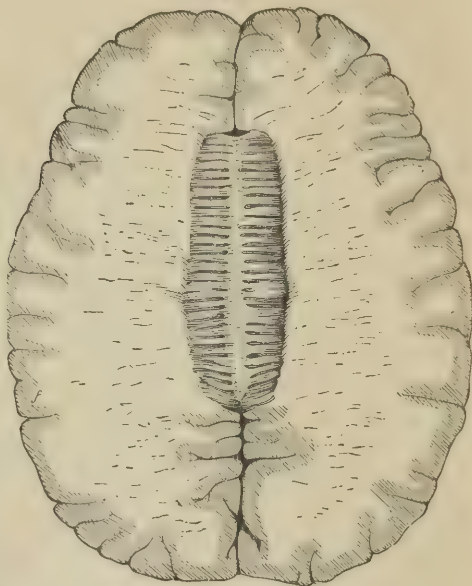
The cerebrum presents exteriorly a surface marked with curved pojections called the convolutions. On making a section of the organ, we find that the interior portion is composed of white or conducting nervous tissue, outside of which there

What is the function of the sympathetic? Does it rest during sleep? What is the function of the cerebro-spinal system? What parts compose the cerebro-spinal system? What is the weight of the brain? What are the divisions of the brain? What are the convolutions of the cerebrum? Is the gray or the white substance on the exterior in the cerebrum?

Fig. 125.

The Cerebrum.

Fig. 126.



Section of the Cerebrum.

is a layer of gray originating material. By throwing the external gray layer into folds and convolutions, an enormous surface is gained, on which innumerable blood-vessels form a sheet of interlacing capillaries.

The membranes of the brain are three in number: 1st. The blood-vessel layer, mentioned above, which dips down into the spaces between the convolutions, to supply the gray substance freely with blood: it is called the *pia mater;* 2d. A serous membrane, which passes over the convolutions, but does not enter the depressions. Like other serous membranes, it forms a sac and contains fluid, so that the brain rests on a water cushion, which protects it from violence, and equalizes pressure: it is called the *arachnoid.* The third membrane nourishes the bones of the cranial cavity, and is called the *dura mater;* it is, in reality, the periosteum of the cranial bones.

The cerebrum is divided laterally into two parts, called the right and left hemispheres, each of which is subdivided into an anterior, middle, and posterior lobe. From the base of the cerebrum, on each side of the median line, the cranial nerves take their origin, and pass to the various organs with which they are connected.

What is gained by the convolutions into which the gray matter is thrown? What are the membranes of the brain? Describe the pia mater. What is the arachnoid? Describe the dura mater. What are the subdivisions of the cerebrum? Where do the cranial nerves take their origin?

Fig. 127.

Base of the Brain.

In *Fig.* 127, *a* is the anterior lobe; *c*, middle lobes; *g*, posterior lobes; *x*, longitudinal fissure; *y*, *y*, fissure of Sylvius; *t*, the optic chiasm; *z*, corpora albicantia; *d*, the pons varolii; *e*, the medulla oblongata; *n*, spinal cord; 1, the olfactory bulbs and nerves; 2, the optic; 3, motor oculi; 4, pathetic; 5, tri-facial; 6, external motor oculi; 7, portio dura and mollis; 8, pneumogastric, glosso-pharyngeal, and spinal accessory; 9, hypoglossal.

Many of the cranial nerves, as the optic, arise from distinct ganglia; we may therefore regard the cerebrum as being composed of a number of ganglia, which possess special functions.

Fig. 128.

The Cerebellum.

The cerebellum consists of parallel plates, and is covered by the membranes of the brain. From it columns of nervous substance pass, to unite with other similar columns from the cerebrum, to form the medulla oblongata, which is connected with all the great ganglia at the base of the brain, and is the commencement of the spinal cord.

The spinal cord is placed in the vertebral column, and terminates below in the canal of the sacrum, by dividing into a number of branches, called the cauda equina. The shape of the cord varies, as is shown in the following figure, which represents sections of different portions. On examining such sections, we find that the bulk of the spinal cord is composed of white nervous substance, arranged in six columns, an anterior,

What is the composition of the cerebellum? How is the cerebellum connected with the cerebrum? What is the medulla oblongata? What is the cauda equina? How is the white substance of the cord arranged?

Fig. 129.

Sections of Spinal Cord.

middle, and posterior column on each side. These inclose a certain portion of gray substance, which occupies the central regions of the cord. The proportion of gray material varies, as is shown in the sections in *Fig.* 129.

Exteriorly the spinal cord is covered by a series of membranes similar to those of the brain, and of which they may be regarded as continuations. The first membrane is composed of the blood-vessels which nourish the organ; the second affords protection; and the third is analogous to the dura mater. From the anterior and posterior columns of the cord the nerves of the body take their origin; they are all formed of white nervous substance, and convey impressions to and from the nervous centres or ganglia.

The nerves of the head are derived directly from the base of the brain. Many of them are engaged in special functions, as the optic, olfactory, and auditory, while others are distributed to the muscles and skin of this region. The nerve which supplies the facial muscles is called the facial; it passes over the masseter muscle, and is the chief nerve of expression, as is demonstrated by the blank, expressionless appearance of one side of the face when the facial nerve of that side is injured.

The nerves of the trunk, upper and lower extremities, are derived from the spinal cord. They originate in the anterior and posterior columns of the cord, and pass out through foramina between the vertebræ. In *Fig.* 130, *a* is the cervical portion, with its nerves; *b*, the dorsal portion and nerves; *c*, the lumbar portion and nerves; *e*, the pons varolii.

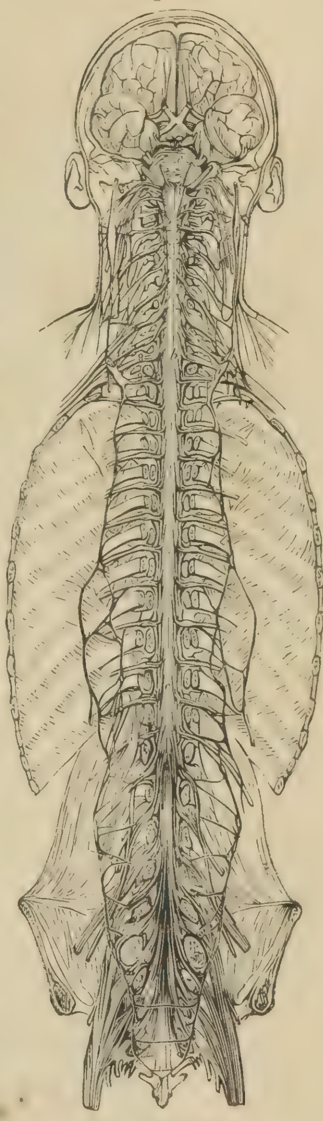
In the neck the first four spinal nerves unite soon after emerging from the vertebral column, and form a plexus, from

What are the membranes of the cord? From what parts of the cord do the nerves take their origin? Describe the facial nerve. Describe the cervical plexus.

which branches are given to the muscles about the shoulder. The remaining four cervical and first dorsal form the brachial plexus, from which the axillary, median, radial, and ulnar nerves are derived, and, passing down the arm in the vicinity of the arteries, are distributed to the muscles of the upper extremity.

The dorsal spinal nerves pass with the intercostal arteries in the groove in the under edge of the rib. The sacral nerves unite to form the great sacral plexus, from which the largest nerves in the body, called the sciatic or ischiatic, are derived. They pass down the legs, giving branches to the muscles of the lower extremities, and accompanying the arteries in their course, and bearing the same names. In addition to the nerves and plexuses mentioned there are many others, but we must refer the reader to the works on anatomy for their description.

Fig. 130.



The Spinal Cord.

LECTURE XXX.

FUNCTIONS OF THE DIFFERENT PARTS OF THE NERVOUS SYSTEM.

Function of the white Substance.—Rapidity of the Conveyance of Impressions.—Simple Ganglia.—Registering Ganglia.—Influential Ganglia.—Relations and Functions of the Nerves, Spinal Cord, Ganglia at the Base of the Brain, and of the Cerebrum to each other.—Functions of the Cerebellum.—Review of the Functions of the Divisions of the Nervous Mechanism.

Having described, as far as our limited space permits, the anatomy of the nervous system, we next pass to the explana-

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Describe the brachial plexus. How are the dorsal spinal nerves distributed? Where is the sacral plexus? Describe the sciatic nerve.

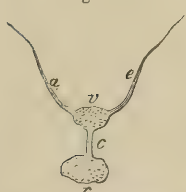
tion of the functions of the different parts, as far as they are understood.

It is the province of the white matter to conduct the nervous force, as is clearly demonstrated by the fact that if we cut a nerve all power of motion and sensation are lost in the parts supplied by it; but if to the lower cut extremity of the nerve an electric current is properly applied, movements are produced in the muscles supplied by the nerve, while, if the upper cut extremity is irritated, pain is felt, which is referred to the same muscles or regions. The rate of transmission of impressions along the fibres bears a direct ratio to the temperature of the animal. In man it is about 200 feet in a second.

In a similar manner, we may satisfy ourselves that the gray matter originates the force, for if the gray substance of the ganglia is destroyed, the power of originating motion is lost, though the nerves still retain their conducting power unimpaired, as may be shown by testing them with the electric current.

The ganglia, as has been stated, are composed of gray substance. They not only originate the nervous force, but, under certain circumstances, they also become the repositories of every species of nervous manifestation. In such registering ganglia thoughts and impressions are stored away, the previous existence of which is almost forgotten, until by some incident they are recalled in all their pristine vigor and clearness.

Fig. 131.



Registering Ganglion.

In the adjoining figure, the relation of the registering ganglion to the simple ganglion is shown; *a* and *e* are the poles or nerves conveying impressions to and from the simple ganglion, *v*, which is connected by another nerve, *c*, to the registering ganglion, *r*. The impression brought to the ganglion *v* by the afferent nerve *a* is registered, or in part retained by the ganglion *r*, which also holds in reserve a part of the force generated in *v*, and conveyed along the efferent nerve *e* to produce motion in the parts to which *a* and *e* are distributed.

The fibres which form a nerve are engaged in two distinct actions: some, like *a*, are afferent, and convey the impressions to the ganglion, while others, like *e*, are efferent, and convey

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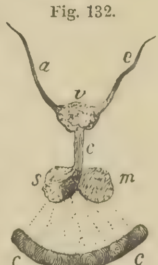
How is it proved that the nerves convey impressions? What is the rapidity of conveyance of impressions along the nerves in man? What determines the rate of conveyance? What is the duty of the gray matter? What are registering ganglia? What is the relation of the registering to the simple ganglia? Do all the fibres of a nerve convey impressions in the same direction?

the motor force to the muscles. When we irritate the sole of the foot of a person who is sleeping, the impression is conveyed along the afferent fibres of the nerve to the spinal cord, and through the efferent fibres the nervous force is sent which is to produce movement in the muscles attached to the irritated member. Such motions occur without the knowledge of the individual, and may be produced in animals in which the spinal cord is cut; they are therefore called reflex actions.

It has been stated in a previous paragraph that the spinal cord takes its origin in certain ganglia at the base of the brain. The relations of these to the cord and nerves are similar to those shown in *Fig.* 131. The nerves are the poles *a* and *e*; the spinal cord is the simple ganglion *v*, and the ganglia at the base of the brain represent the registering ganglion, *r*.

Fig. 132.



Influential Ganglion.

In the diagram, *Fig.* 132, a more perfect development is illustrated. The registering ganglion is divided so that one portion, *s*, takes charge of the sensations, while a second, *m*, superintends the motions to be produced. Another element has also appeared, the influential ganglion, *c c*, as it is called, which is represented in man by the cerebrum.

Upon the size and development of the cerebrum the position of the individual in the scale of intellect depends, the anterior lobes seeming to be the special seat of intellectual power. Mere bulk is not the only element of size in the cerebrum, for we must also consider the extent of gray matter exposed to the action of blood-vessels. A cerebrum which has deep fissures between its convolutions possesses more power than another which has greater bulk but shallow fissures.

In the works on phrenology the cerebellum is supposed to be the seat of the sexual passions, but this is not the case, for a large part of the organ may be destroyed without injury to the procreative power. The true function of the cerebellum is to co-ordinate the forces which have been created in the ganglia of the brain, and produce regularity in the action of muscles which are to execute required movements. That this is the true explanation of its function has been demonstrated in

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Describe the action of the afferent and the efferent fibres. What are reflex actions? What is the relation of the spinal cord to the ganglia at the base of the brain? What is the influential ganglion? What is the relation of the cerebrum to the ganglia at the base of the brain and the cord? What determines the intellectual power? Is the cerebellum the seat of sexual passion? What is the duty of the cerebellum?

the most satisfactory manner by vivisections on animals, in which all attempts at motion in a straight line are destroyed by injuring certain parts of the cerebellum. An animal so treated can only move in a curved or circular course, and no longer possesses the power of co-ordinating the action of its muscles.

In order that there may be no obscurity regarding the functions of the different parts of the nervous system, we restate them in a condensed form.

The sympathetic system regulates the processes of organic or vegetative life.

The cerebro-spinal axis presides over the manifestations of animal life.

The nerves are the channels of communication between the ganglia, and organs, and tissues, conveying sensation and action.

The spinal cord is a simple ganglion, and can originate mere reflex actions.

The ganglia at the base of the brain are the registering ganglia, which also possess the power of originating nervous force.

The cerebrum is the final registering and influential ganglion.

The cerebellum is the co-ordinating ganglion. It is the binding-room of the printing-house of the brain, in which the plates and pages that have been formed in the engravers', compositors', and press rooms, or ganglia of the establishment, are placed in proper relation to each other, so as to form a book, which may be boxed up with other works taken from the repository or cerebrum, and sent down the dumb-waiter or spinal cord to fill an order received through the telegraph or afferent nerve by the railroad or efferent nerve.

How is the function of the cerebellum demonstrated? What is the function of the sympathetic nerve—of the cerebro-spinal system—of the nerves—of the spinal cord? What is the duty of the ganglia at the base of the brain—of the cerebrum—of the cerebellum?

LECTURE XXXI.

THE SPECIAL SENSES.

The Five Senses.—The Sense of Touch.—Its Location.—The Skin described.—The Papillæ.—Acuteness of Sensation depends on the number of Papillæ.—Sense of Touch corrects that of Vision.—Sense of Touch and of Temperature are distinct.—Localization of Touch in Lower Animals.

THE special senses by means of which man is brought in communication with the external world are five in number—Touch, Taste, Smell, Hearing, Vision; of these, the senses of touch, taste, and smell act by direct contact. The first is found in the lowest forms of animals; it is the simplest in its construction and method of action; we shall therefore first examine into the anatomy and physiology of touch.

This sense is situated chiefly in the skin, which is composed of two layers; the exterior is called the cuticle, and is formed of epithelial cells, which arise from the lowest portion of the layer, and gradually become thinner as they are more exterior, until finally they become scale-like, and are rubbed off by contact with various substances.

The function of the cuticle is to protect the parts lying beneath it. In man and the majority of animals it is protected against the action of the air, and kept soft and flexible by a peculiar oil secreted by special glands; in fishes and creatures which live in the water it is covered by a thick mucilaginous material which answers the same purpose.

When the cuticle is subjected to continual pressure it becomes gradually thickened, as, for example, on the soles of the feet, where it reaches a thickness of an eighth of an inch. Sometimes the induration is very small in extent and circumscribed, forming corns, which produce severe pain, not only from their own sensitiveness, but by pressing on the nerves of the cutis vera.

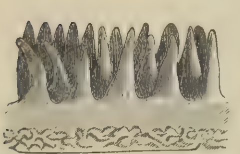
The cutis vera, true skin, or derma, is freely supplied with

Name the special senses. Which senses act by direct contact? Which is the simplest sense? Describe the external layer of the skin. What is the function of the cuticle? How is the skin enabled to retain its softness and flexibility? What are corns? What names are given to the second layer of the skin?

nerves, which terminate in a loop covered by cuticle, forming a projection called a papilla. The papillæ are scattered all over the body, but are very numerous in the fingers, which are in man the special organs of touch; on them the papillæ are arranged in rows, which cover the anterior surface of the hand and fingers.

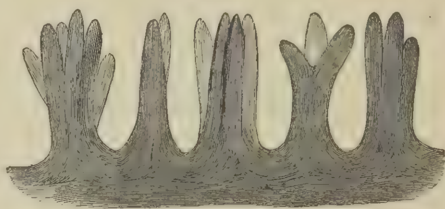
The papillæ which form the ridges of the tips of the fingers are about $\frac{1}{250}$th of an inch in diameter, and $\frac{1}{100}$th of an inch in height. In form they are conical, as is shown in the following figures.

Fig. 133.



Simple Papillæ, 35 Diameters.

Fig. 134.



Compound Papillæ, 60 Diameters.

The greater the number of papillæ in any part, the greater is its sensitiveness, as is demonstrated by bringing the points of a pair of compasses in contact with the skin of various parts of the body, when we find that in those parts where the papillæ exist in greatest numbers both the points of the compass can be distinguished distinctly when separated by the smallest interval. By means of the same device we can readily determine the region of greatest sensitiveness; on the tip of the tongue the points cease to be distinct, and merge into one, when the interval is reduced to $\frac{1}{24}$th of an inch; on the tip of the finger the same result is produced when it is $\frac{1}{12}$th; on the lips, $\frac{1}{6}$th; on the tip of the great toe, $\frac{1}{2}$ an inch; and the middle of the thigh, $2\frac{1}{2}$ inches.

By means of the papillæ two distinct orders of impressions are appreciated: 1st. *Pressure*, which acts mechanically; and, 2d. *Temperature*, which acts chemically, by producing variation in the rate of waste and nutrition.

Through pressure or contact with various objects the sense of touch becomes of great importance to the superior sense of vision, for the latter is to a certain degree educated by the former before it reaches perfection. The eye can of itself determ-

What are the papillæ? What is their size? How are they arranged on the fingers? How does the number of papillæ affect the sensitiveness of any part? Name the order of sensitiveness of various parts of the body. How do pressure and temperature affect the papillæ?

ine the crude outline of an object, but it can not appreciate solidity until it has first been educated by the sense of touch. This fact was demonstrated satisfactorily by the case of Franz, in which an operation for congenital cataract was performed on the patient after he had received the information usually imparted to the blind. The operation was successful, and the patient obtained a very fair degree of vision. On presenting to him a cube, he thought it was a square; a sphere and a disc both appeared to be circles. When the objects were placed in his hands he immediately recognized their true figure, and was surprised at his stupidity in committing such errors.

Under certain conditions the sense of touch is singularly deceived, as, for example, in the experiment of Aristotle, in which a pea or other small sphere is rolled under the tip of the index and middle fingers. So long as the fingers are in their natural position, the individual has no difficulty in stating under which finger-tip the pea is, but when the fingers are crossed over each other, there is often the greatest uncertainty in the mind of the experimenter regarding the position of the pea.

If we pass the tip of one finger over any surface, we can readily discover whether it is flat, convex, or concave; but if another person takes hold of the finger, and passes it over the surface, he may deceive us completely regarding its nature. If the surface is flat, and he presses the finger more when passing over the centre than at the circumference, he will induce us to think that it is concave; by pressing less at the centre, it will be made to appear convex.

Sometimes sensations which originate in the brain are referred to the skin of various parts of the body; these are often very disagreeable and annoying, being likened by the sufferer to the crawling of ants, or some such uncomfortable impression.

The sense of temperature is distinct from that of contact, or true touch, as is demonstrated by the fact that in paralysis the first is often destroyed, while the second remains; and the unfortunate individual, having lost the appreciation of the vicinity of hot substances, is sooner or later severely burnt.

In appreciating temperature, the skin acts more like a calorimeter than a thermometer, measuring rather the quantity than

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How does the sense of touch correct that of vision? Relate the case of Franz. Under what circumstances may the sense of touch be deceived? Can sensations affecting the organ of touch originate in the brain? How is it demonstrated that the sense of touch and that of temperature are distinct? Does the skin measure the intensity of the temperature only?

the intensity of the heat to which it is exposed. Of this any one may satisfy himself by placing his finger in a vessel of hot water, and then immersing the whole hand. The intensity of the heat seems in the latter instance to be far greater, yet we know that it is the same in both cases. Appreciation of temperature by the skin is therefore very uncertain, unless we take into account the extent of surface exposed.

In many animals the sense of touch is specially developed in some part of the body. In the hog it is in the snout; in the elephant, in the trunk; in insects it is usually in the palpi, near the antennæ, or feelers.

LECTURE XXXII.

TASTE AND SMELL.

Tissues composing the Tongue.—Sensations appreciated by it.—The Papillæ described.—Distribution of the Senses of Touch and Taste on the Organ.—Action of the Papillæ under the Influence of strong Flavors.—Deception of the Organ of Taste.—Location of the Sense of Smell.—Divisions of the Nasal Cavity.—Distribution of the Olfactory Nerve.—Conditions essential to the proper Action of the Sense of Smell.—Inverse or subjective Sensations.

The sense of taste is placed in the buccal cavity, and is situated in the tongue, and not in the palate.

The tongue is composed of muscles, which are covered by mucous membrane, and freely supplied with blood-vessels and nerves; it is consequently capable of a great variety of movements, assisting in the production of certain sounds called linguals, and by its sensitiveness enabling us to select those articles of food which are suited to the wants of the system.

The tongue is capable of three distinct classes of sensation, viz., touch, temperature, and taste. The first and second are most acute at the tip, and gradually fade away toward the base, while the sense of taste is dull at the tip, and acute at the base of the organ.

The papillæ of the tongue are of two classes, some being small and others large. The first are most numerous at the tip, and are the papillæ of touch, while the large papillæ, in which

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Mention the special location of the sense of touch in some of the lower animals. Where is the sense of taste located? What tissues compose the tongue? What are the three sensations appreciated by the tongue? How are the senses of touch and taste distributed on the tongue? Describe the papillæ of the tongue.

the gustatory nerve, or nerve of taste, commences, are found at the base of the organ in the greatest numbers.

Fig. 135.

The Tongue.

In order that any substance should affect the sense of taste, it must be soluble in saliva; all bodies insoluble in that fluid are tasteless. Salt, by increasing the solubility of various materials, renders them more gratifying to the palate; it is therefore highly prized as a condiment, together with many other articles, as pepper, mustard, etc.

Under the influence of strong flavors like vinegar, the papillæ change their figure, becoming elongated and pointed; it is therefore probable that the sensation of taste may be produced by the tension to which the nerves are subjected.

The sense of taste is intimately connected with that of smell, as is demonstrated by the fact that many substances lose their taste when the nostrils are closed; but this is by no means the case always, for there are many articles, like quinine, which affect the sense of taste powerfully, but are without any action on that of smell.

As the sense of touch may at times be subjected to deception, so that of taste may also be easily deceived. A smart, quick blow delivered on the tongue gives the impression of a strong flavor; an electric current produces a metallic taste; and a jet of air thrown on the tongue gives a sensation similar to that produced by saltpetre. Impressions which originate in a disordered condition of the brain will also produce impressions similar to those caused by flavors, being sometimes pleasant, but usually disagreeable.

Temperature possesses considerable influence over taste. A very hot or a very cold liquid taken into the mouth seems to affect the papillæ so profoundly that some few seconds must elapse before they regain their power.

SMELL.

The sense of smell is situated in the nasal cavity, which is

What condition is essential in order that a substance should affect the organ of taste? How does salt affect the flavor of articles of food? How do strong flavors like vinegar affect the papillæ? Does the same substance always affect the organ of taste and that of smell? What impressions may deceive the sense of taste? How does temperature affect the sense of taste? Where is the sense of smell situated?

Fig. 136.

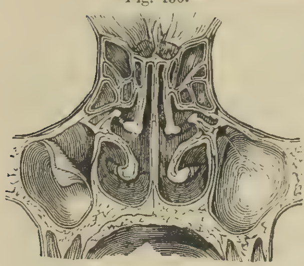
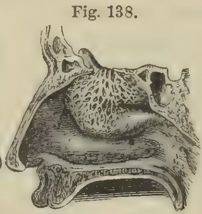


Fig. 137.

Distribution of Olfactory on Septum of Nose.

Fig. 138.



Distribution of Olfactory on outer Wall of Nasal Cavity.

divided by the vomer into two lateral portions, each of which is subdivided by the turbinated bones into a superior, middle, and inferior meatus. The sides of the cavity, and the thin, scroll-like plates of the turbinated bones, are covered by mucous membrane, called the Schneiderian membrane. To it the nerve of smell, or olfactory, is distributed, the greatest portion of the nerve passing to the upper meatus, so that when the odor is feeble or delicate, the air is drawn in strongly, to carry the odoriferous particles into the upper part of the cavity.

In order that substances should affect the organ of smell, they must be capable of assuming either the vaporous condition, or such a fine degree of subdivision as to be readily drawn in by the currents of air introduced during respiration. The conveyance of odoriferous particles by currents of air precludes the necessity of mobility in the organ of smell; it is therefore stationary in nearly all animals.

The senses of taste and smell are confined in their action when compared with those of hearing and vision. The eye can at a glance perceive a host of objects; the ear can detect many sounds; but the sense of smell can appreciate but one odor at once, failing to discover those which are feeble, if at the same time one which is powerful is present.

The special function of the sense of smell is to enable animals to discover the presence of substances suitable for food. The carnivora, in whom the turbinated bones are wonderfully extended and intricate, affording a very large surface for the distribution of the olfactory nerve, can discover the presence of food which is hidden from sight. The herbivora will, in pasturing, select out the tender blades of grass, and avoid all offensive weeds, by the aid of this sense.

In reptiles it is developed to a very slight extent; in birds

What are the divisions of the nasal cavity? Give the name of the mucous membrane of the nasal cavity. What is the name of the nerve of smell? To which meatus is it chiefly distributed? What condition is essential in order that substances should affect the organ of smell? What is the object of the sense of smell?

it is more perfect; but even the carnivorous birds do not depend upon it to discover their food, as was shown by Audubon, who stuffed the skin of a donkey with straw, and hid the carcass of the animal under leaves in a ditch in the vicinity, when he found that the buzzards quickly discovered the stuffed skin, but failed to find the highly-odoriferous carcass.

The sense of smell is developed to the highest degree in the carnivora, but yet there are peculiarities connected with it which are very singular. A dog, that can without difficulty discover his master in a dense crowd, or follow him for a great distance by the odor of his footsteps, seems to take no notice of the perfume evolved by a rose, while any of the herbivora would perceive it instantly.

Among the numerous substances which the fashionable people of all nations have adopted as luxuries, none are more extraordinary than those employed as perfumes. Ladies are disgusted by the man who indulges in chewing tobacco; but what is to be said of the apparently delicate, refined woman, who renders her presence insufferable by the use on her person of fashionable perfumes, derived from intestinal or other secretions of certain animals?

As was the case with the senses of touch and taste, so the sense of smell may annoy an individual with odors which have no real existence, but are imaginary, being the product of his own disordered nervous system. To these phenomena the designation of inverse or subjective sensations are given, and we shall find that they exist in connection with the senses of hearing and vision as well as with touch, taste, and smell.

LECTURE XXXIII.

PROPERTIES OF SOUND.

General Properties of Waves.—Reflection and Interference of Waves.—Nature of Sound.—Analogy of Sound Waves to Water Waves.—Action of the Ear Trumpet.—Velocity of the Passage of Sound in various Media.—Effect of Variation of Density of Air on Velocity of Sound.—Non-conducting Power of Inelastic Bodies.—The Pitch and Quality of Notes.

THE ear is the organ of time, and determines the rapidity with which sounds succeed each other. It is very complex in

Do the carnivorous birds hunt by sight or smell? In what class of animals is the sense of smell developed to the highest degree? What are inverse or subjective sensations?

its construction, and, in order to appreciate the functions of its different parts, we must first devote some space to the consideration of the nature and properties of sound.

If a stone is cast into perfectly calm water, a ripple originates from the point at which it strikes the fluid, and is propagated in a series of concentric waves to the edges of the vessel containing the liquid.

The waves thus produced on water are measured in two ways: first, from the crest of one wave to the crest of the next, the distance being called the wave length; second, from the bottom of the depression to a horizontal line connecting the crests: this measurement is called the wave height.

When the waves reach the walls of the vessel containing the liquid they are not lost, but, being reflected backward, produce a return system of waves, which, if their crests correspond to the crests of the original system, produce a higher wave; but if the crests of the second system correspond to the depressions of the first system, they neutralize or interfere with each other, and smooth water is the result.

As, in the foregoing instance, the vibration caused by the impact of the stone on the water is propagated through it in the form of waves, so the rapid vibrations of a sonorous body are propagated through the air as waves, which, falling on the ear, produce the impression of sound. They may be subjected to measurement just as waves on water are measured, and their length and height accurately determined. The phenomena of reflection and interference of water waves are also shown by waves of sound. If two systems of waves of sound are arranged so that the crests of one correspond to the depressions of the other, they completely neutralize each other if their intensity is equal, silence being produced.

Though waves of sound are analogous to water waves, they are by no means identical; for while the latter pass along a single plane, and produce concentric circles of compression or elevation, the waves of sound are propagated along every conceivable plane, passing through the vibrating body as a centre, forming concentric spheres of compression.

Since waves of sound radiate from a central point of origin, they gradually diminish in intensity as they occupy a greater space; but when they fall on a concave surface, they are re-

How may waves be measured? What is wave height? What is wave length? Can waves be reflected? What is meant by the interference of waves? What is sound? Can the waves of sound be measured? What is the result of the interference of two systems of sound waves? What is the difference between waves of sound and waves on water?

flected to its central point or focus. This fact is taken advantage of in the construction of various instruments, such as the ear trumpet, by which a great number of waves are collected and conveyed into the ear, and the intensity increased, thereby enabling a person who would otherwise be perfectly deaf to hear with comparative ease.

When waves of sound fall on dense media they are not lost, but a portion are reflected, while the remainder are transmitted along the medium. Air, therefore, is not absolutely necessary to the existence of sound; but, since sounds almost always come to us through it, the various phenomena connected with them are always referred to air as the medium, unless it is otherwise specified.

The rate of transmission, or velocity of sound, depends in a great measure upon the density of the medium through which it is passing; the other element of velocity is the elasticity of the medium. If we notice a bricklayer working at a suitable distance, we remark that in cutting a brick the sound seems to be produced when the trowel is in the air, and not at the moment of striking the brick: this is due to the fact that a certain amount of time is required for the sound to reach the position in which we are standing. Another peculiarity which we can not avoid remarking is, that instead of the sound being single, it is double. This is explained by the fact that in passing to the observers the sound has in part come through the air, and in part along the wall and earth; in the latter medium it moves with greater rapidity than in the former. The sound which was originally single has therefore become doubled by passing through two media with different rates of velocity.

The most recent experiments have shown that the velocity of sound in the air is 1123 feet per second; in water, 4700; and in rock from 7000 to 12,000, depending upon its density, being the highest in the densest rocks.

By producing variation in the density of any given medium, we can cause the rate of velocity of sound in it to vary. For example, atmospheric air, if subjected to compression, transmits sounds with greater velocity, and the intensity is reduced in a less degree; while if it is submitted to a process of exhaustion,

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What is the effect of concave surfaces on waves of sound? How does the ear trumpet act? Is air the only medium in which waves of sound may be conveyed? What determines the velocity of the movement of sound? Give an illustration of the difference of velocity of movement of sound in air and a denser medium. What is the velocity of sound in air—water—rock? Does sound move with equal velocity in all rocks? What is the effect of increasing and diminishing the density of air on its power to convey sound?

so as to reduce its density, the conducting power is steadily diminished, until finally it is entirely lost, and we fail to hear a bell which is ringing violently in the air-pump jar when the density of the air is sufficiently reduced.

Substances devoid of elasticity almost destroy sounds, for they neither transmit nor reflect them readily, as any one may satisfy himself by attempting to speak in a room covered with tapestry. While the sides are bare they reflect sounds so that the voice can be heard without any difficulty, but as soon as the walls are draped with cloth, the waves, falling on the soft, inelastic surface, are destroyed, and it becomes almost impossible to hear the voice in the distant parts of the room, even when it is exerted to its utmost power.

In addition to the properties already mentioned, sound possesses three distinct characteristics; they are, 1st. Intensity or loudness; 2d. Pitch or note; and, 3d. Quality.

The intensity of a sound is determined by the wave height. Two sounds may have the same wave length, but that which has the greatest wave height has the greatest intensity.

The pitch is regulated by the wave length, or time of vibration. The more rapid the vibrations, the shorter is the wave length, and the higher the pitch of the note.

By the quality of a note we mean to express the differences that exist in a note of any given pitch when it is produced by various instruments. Any one can tell whether a given note is produced by a piano or a violin; in both instances the note is the same, and yet there is some difference by which we recognize the instrument which produced it.

It is not known on what peculiarity of the sound wave the quality of a note depends; but in the ear, both in man and the lower animals, there is, as we shall find, a special mechanism set aside for the determination of the quality, as well as the pitch and intensity of notes.

In addition to the pitch, intensity, and quality of a sound, the ear also determines its direction. It is to be remembered that the course of a sound is represented by the radii of a sphere, of which the point of origin is the centre; but it must not be forgotten that sounds are reflected by opposing surfaces, so that when a number of such surfaces are in proper re-

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What other element besides density influences the rate of conduction of sound? Give an example of the failure of inelastic substances to conduct sound. What are the three properties of sound? How is the intensity of sound regulated? How is the pitch of a note regulated? What is meant by the quality of a note? What is the course of waves of sound?

lation to each other, the sound can be made to double around the first surface, and be readily heard behind it.

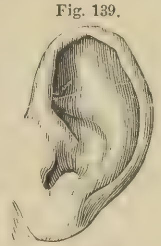
LECTURE XXXIV.

ANATOMY OF THE EAR.

Divisions of the Ear.—External Ear described.—Formation of Wax—The Tympanic Cavity and Membrane.—The Bones of the Ear.—The Eustachian Tube.—Openings in the Walls of the Tympanic Cavity.—Muscles of the Tympanic Cavity.—The Parts of the Internal Ear.—The Vestibule described.—The Membranous Labyrinth.—The Perilymph and Endolymph.—The Otoliths.—The Saccule and Utricle.—The Semicircular Canals.—The Cochlea.—The Lamina Spiralis, Modiolus, and Spiral Canal.—The Helicotrema.—Distribution of the Auditory Nerve to the Internal Ear.

THE ear is divided into three parts for convenience of description. They are called the external, middle, and internal ear. The external ear consists of the pinna and auditory canal. The pinna is composed of cartilage, which is covered by skin, and thrown into curved folds, which direct the waves of sound into the auditory canal.

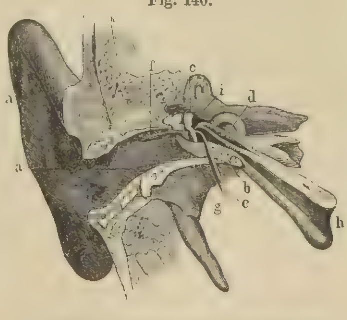
Fig. 139.



The Pinna.

The auditory canal conveys the waves to the middle ear; it is about one inch in length, and is terminated below by the tympanic membrane, or drum of the ear. It is slightly curved, with the concavity downward, and is lined with hairs and glands that secrete an acrid, oily material, which prevents insects entering the organ. The secretion of these glands, when dried, forms the wax found in the ear.

Fig. 140.



External, Middle, and Internal Ear.

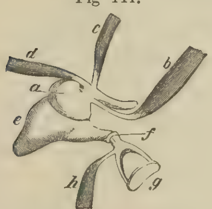
Fig. 140, *a a*, pinna and auditory canal; *b*, middle ear or tympanic cavity; *c*, hammer and its muscles; *d*, internal muscle; *e*, anterior muscle; *f*, external muscle; *g*, interior half of membrana tympani; *h*, Eustachian tube; *i*, internal ear or labyrinth.

What are the divisions of the ear? What parts compose the external ear? What is the action of the pinna? What is the length and shape of the auditory canal? Where does it terminate? How is the wax of the ear formed?

The middle ear or tympanic cavity is situated in the petrous part of the temporal bone; it is closed exteriorly by the tympanic membrane. It contains three small bones, and communicates with the back part of the buccal cavity, or pharynx, by means of the Eustachian tube. It is very irregular in its form, and is filled with air; in its bony walls there are a number of openings, viz., 1st. Meatus externus, or auditory canal, closed by tympanic membrane; 2d. The opening of the Eustachian tube; 3d. The fenestra ovale, and, 4th. The fenestra rotunda, both of which communicate with the internal ear, and are closed by membranes; 5th. The opening to the mastoid cells, which are lined by a continuation of the mucous membrane of the tympanic cavity; 6th. The openings for the muscles and their tendons.

The small bones contained in the tympanic cavity are called the malleus or hammer, the stapes or stirrup, and the incus or anvil, on account of the resemblance they bear to those implements. They are connected together, forming a chain which extends across the tympanic cavity from the membrana tympani to the fenestra ovale, the malleus, *a*, being attached to the tympanic membrane, and the stapes, *g*, to the fenestra ovale. To the handle of the malleus, near its root, the tensor tympani, *b*, the chief muscle of the ear, is attached; the two laxator tympani muscles, *c*, *d*, are also attached to the same bone, while the stapedius, *h*, is inserted into the stapes. By means of these muscles the membrana tympani can be relaxed or stretched, and pressure produced on the contents of the internal ear by the insertion of the stapes into the membrane of the fenestra ovale.

Fig 141.



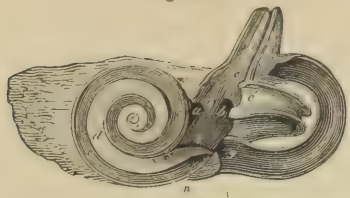
The Ossicles and Muscles.

The mucous membrane of the tympanic cavity is very thin and highly vascular; it is continuous with the mucous membrane of the pharynx by the Eustachian tube, and covers the ossicles, tendons, and muscles contained in the cavity.

The internal ear is called the labyrinth on account of the irregularity of the parts composing it. It consists of the vestibule (*a*, *b*, *t*, *Fig.* 142), semicircular canals (*o*, *g*, *c*, *Fig.* 142), and

Where is the middle ear? What name is given to it? How does the tympanic cavity communicate with the pharynx? What openings are found in the walls of the tympanic cavity? What are the names of the bones of the tympanic cavity? To what membrane is the malleus attached? To what membrane is the stapes attached? What muscles are found in the tympanic cavity? To what part of the malleus is the tensor tympani attached? What is the action of these muscles? Describe the tympanic mucous membrane. What name is given to the internal ear? Name the parts composing the labyrinth.

Fig. 142.



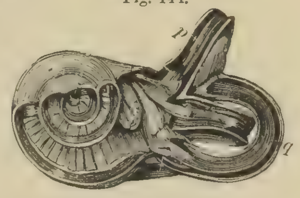
Labyrinth magnified two Diameters.

Fig. 143.

Exterior of the three Semicircular Canals and the Cochlea.

cochlea (*n*, *d*, *e*, *Fig.* 142), which are hollowed out in the petrous part of the temporal bone, and communicate externally with the middle ear, and internally with the meatus internus, through which the auditory nerve passes.

Fig. 144.



Membranous Labyrinth of the Canal.

The vestibule is ovoid in figure, and the centre of communication of the other divisions of the internal ear; it is lined interiorly by a membrane that contains a fluid called the perilymph. In this fluid a sac-like body, called the membranous labyrinth, is placed, which is not attached to the bony walls of the cavities, but is separated from them by the perilymph.

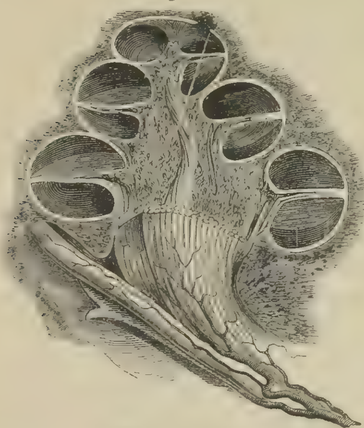
The membranous labyrinth contains the terminal filaments of the auditory nerve, and is filled with fluid. The portion that occupies the vestibule is divided by a central constriction, and caused to assume a dumb-bell shape. To one of the divisions the name of the saccule is given; the other is called the utricle; from it tube-like processes are given off, which occupy the cavity of the semicircular canals *o*, *p*, *q*. The saccule and utricle each contain an otolith, or minute stone-like body.

The semicircular canals are three in number. They are so arranged as to occupy three planes at right angles to each other, represented by the faces of a cube. They are lined by a membrane which contains the perilymph, and in this liquid the tube-like portions of the membranous labyrinth are suspended by the vessels which pass to them to convey the required nutrition. The fluid contained in the membranous labyrinth is almost identical in composition with the perilymph; it is called the endolymph.

Describe the vestibule. What is the perilymph? Describe the membranous labyrinth. What names are given to the divisions of the vestibular portion of the membranous labyrinth? What are the otoliths, and where are they found? Is the membranous labyrinth attached to the walls of the cavities in which it is placed? Describe the semicircular canals. What is the endolymph?

The cochlea resembles in its shape a common snail-shell. It is composed of a central conical axis, called the modiolus, around which a conical tube, called the spiral canal, is wound for two and a half turns. In the spiral canal there is a thin septum, called the lamina spiralis, which is composed of bone, muscle, and tendon, and extends nearly the whole length of the canal, dividing it into two tubes, the *scala vestibuli*, which communicates with the vestibule, and the *scala tympani*. At the apex of the spiral canal the scalæ communicate with each other by an opening called the helicotrema.

Fig. 145.

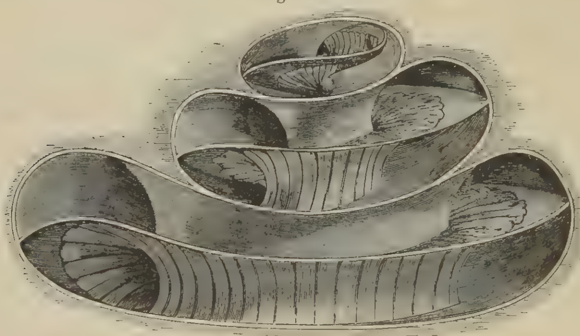


Section of Cochlea.

The fibro-serous membrane which lines the cochlea is continuous with that of the vestibules and semicircular canals; it secretes the perilymph, which is found in all parts of the internal ear.

The portion of the auditory nerve which is distributed to the cochlea passes up the modiolus, and the filaments cross the

Fig. 146.



Distribution of Cochlear Nerve.

lamina spiralis, which is about one tenth of an inch wide at its base, and terminates almost in a point at the helicotrema. The filaments of the nerve are consequently shorter and shorter to-

What is the shape of the cochlea? What is the name of the central axis of the cochlea? What is the spiral canal? What is the lamina spiralis, and of what is it composed? What are the two scalæ, and what names are given to them? What is the helicotrema? What is the nature of the membrane that secretes the perilymph? How is the auditory nerve distributed to the cochlea? Are the filaments of the nerve all of the same length?

ward the apex of the cochlea, and may be regarded as resembling the strings of a harp or piano.

The internal, middle, and a part of the canal of the external ear are contained in the petrous portion of the temporal bone, which, in the articulated skull, lies at its base, so that they are perfectly protected. The dense, compact structure of this bone is very favorable to the conveyance of sounds, and they are retained until they have been analyzed by the mechanism of the ear, when they are destroyed in the ear by a special apparatus.

The auditory nerve gains access to the internal ear by an opening near the apex of the petrous bone, called the meatus auditorius internus, in contradistinction to the opening at its base by which the waves of sound are admitted.

LECTURE XXXV.

HEARING AND VOICE.

The Elements of Sound dealt with by the Ear.—Function of the Pinna and Auditory Canal.—Function of the Membrana Tympani.—Functions of the Ossicles.—Of the Eustachian Tube.—Function of the Vestibule.—Of the Semicircular Canals.—Of the Cochlea.—The Destruction of Sounds in the Internal Ear.—Development of the Ear.—The Ear in the Lower Animals.—Voice exists in Air-breathing Animals.—The Larynx described.—Vocal Cords.—Character of Song.—Of Whispers.—Of Voice or Speech.

THE ear deals with four elements of sound, viz., Direction, Intensity, Pitch, and Quality. The first is found by determining the relative intensity of the impressions produced on both ears, the advantage of a duplication of the organs being that we may be advised of the existence of sounds on all sides, and appreciate their true nature without being obliged to turn the head.

The waves of sound which fall on the pinna are by its curved surfaces directed into the auditory canal; the object of the pinna, therefore, is to increase the number of waves of sound which enter the canal by acting as a reflector.

At the bottom of the auditory canal sound waves come in contact with the drum or tympanic membrane, the tension of

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In what bone are the internal and middle ear placed? How does the auditory nerve reach the internal ear? With what elements of sound does the ear deal? How is the direction of a sound determined? What advantage is gained by the possession of two ears? What is the function of the pinna?

which can be varied by the action of the small muscles inserted into the bones of the tympanic cavity.

If the tension on the membrana tympani is increased by compressing the air in the tympanic cavity through the Eustachian tube, sounds become dull and obscured. When the operations of the muscles attached to the membrane are interfered with, sounds often become almost unendurable from their intensity. It is therefore supposed that it is the function of the tympanic membrane, or rather of the tensor tympani muscle, to measure the intensity of the sound conveyed to the interior of the organ by determining the force required to produce the right amount of tension in the tympanic membrane. At the same time, the volume of sound allowed to enter the ear is also regulated.

It was formerly supposed that the object of the chain of bones was to convey the sounds with greater perfection to the internal ear; but the jointed nature of the apparatus entirely precludes this idea, for such a structure is highly injurious to the conduction of sound. The true function of the bones is to vary the tension of the membrana tympani by applying in an advantageous manner the force produced in the contractions of the tensor tympani and laxator muscles.

The precision and small amount of contraction of the muscles of the ear in their action on the drum is rivaled by those of the larynx, the muscles of the vocal cords being able to produce a variation of one semitone by a contraction of $\frac{1}{17000}$th of an inch.

The object of the Eustachian tube is to give perfectly free communication with the external air, an equality of pressure on both sides of the membrana tympani seeming to be essential to its proper action. Whenever the Eustachian tube is closed from any cause, as in sore throat, by the accumulation of mucus in the inflammations of the mucous membrane of the pharynx, the sounds become muffled and indistinct, and regain their clearness when the tube is again freed from all obstructions.

From the above facts, we conclude that it is the function of the membrana tympani to determine the intensity or wave height of sounds.

There still remain two elements of sound to be ascertained

What is the effect of increasing the pressure on the tympanic membrane? What is the function of the membrana tympani? What is the function of the chain of bones in the tympanic cavity? What is the function of the Eustachian tube? What is the effect of temporary closure of the Eustachian tube?

by the internal ear, viz., Pitch and Quality. It is to be recollected that the vestibule is the entrance to the cochlea and semicircular canals, but it probably has no special function beyond the conveyance of the sound to those organs, the presence of the otoliths in the sacculus and utricle being accounted for by supposing that they are rudimentary relics, like the mammæ in males.

The function of the cochlea is to determine the pitch of the sound, as we shall endeavor to show by the consideration of its construction.

It is a well-known fact in acoustics, that if in the vicinity of any stringed instrument, as a piano, a note is sounded on some other instrument, the corresponding string in the piano will be thrown into vibration, and produce the same note. On the lamina spiralis of the cochlea the auditory nerve is distributed, so that the filaments are of different lengths, like the strings of a piano. Whenever there is similarity of structure, we may argue similarity of action. It is therefore probable, that as the proper string of the piano vibrates in unison with the note produced in its vicinity, so the proper fibrilla on the lamina spiralis is affected by the note falling upon it, and the impression is conveyed to the brain.

When a note has produced its proper effect in the cochlea it becomes necessary that it should be destroyed, or the ear would be filled with the dying echoes of notes that are passing away. The final destruction of the note is accomplished by taking advantage of the principle of interference. It has been stated, in describing the cochlea, that the lamina spiralis divided the spiral canal, so that two tubes, the scala vestibuli and scala tympani, were formed, which are of unequal lengths, and communicate above through the helicotrema. In order to reach the filaments of the auditory nerve, the waves of sound must pass up the two scalæ, and finally meet at the helicotrema in such a manner that the crest of one system of waves corresponds to the depression of the other, and they mutually destroy each other after they have produced their proper impression.

In addition to its formation, there are facts in the comparative history of the organ of hearing in the lower animals which confirm the opinion that the function of the cochlea is to determine the pitch or wave length of sound.

What is the function of the vestibule? How is the presence of the otoliths accounted for? What is the function of the cochlea? Upon what principle does the action of the cochlea depend? How is the formation of echoes in the cochlea avoided? Are the two scalæ of equal lengths?

The semicircular canals were formerly supposed to determine the direction in which a sound came to the ear, because they were placed in three different planes at right angles, but it is now thought that they detect the quality. This conclusion is drawn from facts in comparative anatomy, which show that the canals often exist in creatures which can determine the quality of a sound, but do not possess a cochlea.

The simplest form of ear merely appreciates the existence of sound; it consists of a small sac, containing fluid, and an otolith. When the waves of sound fall on the apparatus, the otolith is caused to vibrate, and, striking the walls of the sac, irritates the nerve fibres distributed to them, and produces the impression of sound. By means of two such organs its direction is determined. The next step in advance is the addition of a tympanum, for measuring the intensity; the semicircular canals, to detect the quality; and, finally, the cochlea, to ascertain the pitch.

In its various stages of development, the ear of the fœtus shows a gradual advancement toward perfection, similar to that we have detailed above, being at first like that of a fish, consisting of a sac and otolith, but finally reaching its perfect state.

There are some singular and interesting evidences among the lower animals of adaptation of means to an end in the auditory apparatus. In the predaceous creature, the pinna and meatus, or auditory canal, are directed forward, so as to enable it to follow its prey, while in timid animals they are directed backward, so as to favor escape during pursuit. Burrowing quadrupeds are provided with membranous valves, to prevent dirt entering the canal during their subterranean operations. Many other interesting instances might be detailed, but we must refer the reader to the works on Natural History, and pass to the consideration of

THE VOICE.

Language is the direct means of communication with our fellow-men. By it we make known to each other our pleasures and sufferings, and express the thoughts, ideas, and commands which control the destinies of men and nations; yet without

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What was formerly supposed to be the function of the semicircular canals? What is the present theory regarding the function of the semicircular canals? What is the simplest form of ear? Through what stages does the human ear pass in its development? Describe some of the peculiarities of the auditory apparatus in the lower animals.

the sense of hearing it is useless; we may therefore regard it as being auxiliary to that sense.

The power of producing a noise appertains to air-breathing animals, creatures which are aquatic not being able to produce sounds by which they may hold communication with other members of their own species. The voiceless state of aquatic creatures is due to the fact that, since they do not possess lungs, there is no expired air to employ for the purpose of producing sounds.

In insects sounds are sometimes formed by the rapid rubbing of horny surfaces against each other; sometimes by the vibration of the wings, as in musquitoes; in others by forcing the air from the trachea or air-tubes through the valves of the spiracles which close the orifices of those organs: a rapid vibration of the valves is the consequence, and sounds are produced in the same manner as in the accordeon.

Fig. 147.

Spiracle of Insect.

In birds there is a double larynx, one being placed at the back part of the mouth, and the other at the bifurcation of the trachea. The first is employed in the ordinary act of respiration, and the second in the production of song.

In man there is but one larynx, commonly known as the Adam's apple. The vocal cords, *r*, *s*, are extended across its opening, *o*, which is protected above by the epiglottis, *i*.

Fig. 148.

The Vocal Cords.

To the cords muscles are attached, by which they may be subjected to various degrees of tension, and the nature of the opening altered. By varying the tension of the cords, and the force with which the air is driven through the chink-like opening they inclose, various notes are produced.

Song is the result of the vibration of the column of air in

What class of animals possess the power of uttering sounds? What are the methods resorted to for the production of sounds? What is the peculiarity in the larynx of birds? Describe the larynx in man. What are the vocal cords? How are the notes produced in singing?

the larynx and trachea, but speech is caused by the action of the tongue, lips, and muscles of the mouth. The simplest form of speech is the whisper; it is produced by forcing a current of air through the buccal cavity, while its parts are thrown into the proper position for producing different words. In speaking the same movements are employed, but, in addition, a note is at the same time formed in the larynx, which is modified as it passes through the mouth, and speech is the result.

An ingenious experiment, first advanced by M. Deleau, has demonstrated the above explanation of the nature of speech in the most satisfactory manner. It consists in passing an elastic tube through the nostrils to the back part of the mouth; through this another person blows gently, while the experimenter throws the parts of the buccal cavity into the positions for producing any given word. The result is a whisper. If, at the same time, the experimenter causes a sound to be produced in his own larynx, there is a double articulation, one as a whisper, the other as audible speech, demonstrating that articulate speech is produced by the mouth.

Speech and language are of great interest to the historian, for by tracing the roots of words of different tongues he can often discover the influence of a conquering on a conquered race, and determine the track through which a nation has passed in its career of conquest or of flight.

LECTURE XXXVI.

NATURE AND PROPERTIES OF LIGHT.

Theories regarding Light.—Existence, Nature, and Properties of the Ether.—Effect of Temperature on the Intensity of Light.—Compound Nature of Light.—Action of Prisms.—Action of Surfaces and Media on Light.—Reflection, and the Law which Governs it.—Causes influencing the Intensity of the reflected Ray.—Transmission.—Absorption.—Interference.—Interference and Prismatic Spectra compared.—Refraction described.—Order of Refrangibility of Colors.—Theory of Coloration of Surfaces.

Until quite recent times, the doctrine of Newton regarding light was almost universally adopted. He taught that it was produced by the emission of exceedingly minute particles from

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What is the difference between song and speech? What is the difference between whispering and speech? Describe the experiment of Deleau. What was Newton's theory of light?

the luminous body, which, falling on the retina, or sensitive nervous coat of the eye, produced the sensation of light.

The *emission theory* of Newton has been finally set aside by the *wave theory*, which was perfected by the researches of Young and Fresnel. It supposes that the particles of the luminous body are in a state of rapid vibration, and produce in the ether waves, which, falling on the retina, give rise to the sensation of light.

The ether, the existence of which is necessary to the wave theory, is supposed to be an exceedingly attenuated medium which pervades all space, exists in the interior of transparent substances, extends among the planets, and fills the interstellar spaces. The presence of such a medium is demonstrated by the fact that comets and like cosmical bodies are subject to variations and retardations in their times of passage through their orbits, which can only be explained by the resistance afforded by some ethereal medium.

The marvelous rapidity (195,000 miles in a second) with which light traverses space, as well as the manner of the movement, is admirably illustrated in the following quotation: "Motion may be propagated and matter affected to a great distance without the transmission of matter itself. Imagine a straight tube filled with peas reaching from London to York in a horizontal position. If I force an additional pea in at one end of the tube, a pea will drop out of the tube almost simultaneously. Now if the means by which this was effected were as imperceptible as the propagation of light, or of electricity transmitted through good conductors, we should be astonished at the rapidity of the transit, and imagine that the identical pea put into the tube in London had arrived at York in an incredibly short space of time; but, knowing the condition of the proposition, we perceive that motion may be propagated throughout a very long line almost instantaneously, without moving each particle of matter far from its original position, or communicating to those particles much momentum."

In 1846, Professor J. W. Draper demonstrated that all solid bodies become luminous at the same temperature. The point at which such substances first become visibly red-hot is 977° Fahrenheit, and their brilliancy steadily increases with the elevation of temperature, so that at 2600° the light emitted is for-

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What is the wave theory? What is the ether? Why is such a medium supposed to exist? At what temperature do solids become luminous? How does increase of temperature affect the intensity of the light emitted?

ty times as intense as at 1900°. Gases, on the contrary, require a far higher temperature than solids to render them visibly red-hot, as any one may satisfy himself by holding a coil of platinum wire over the flame of a spirit lamp. The ascending gas from the flame is not luminous, but the moment the wire is placed in it the temperature is so high as to cause the platinum to emit light, thereby demonstrating that solids require a far lower temperature than gases to cause them to become luminous.

Contrary to what we should naturally expect, white or colorless light is not simple, but compound, consisting of no less than seven different varieties of colored lights. There are a number of experiments which show this fact, for which we are indebted to Newton, who found that if a ray of colorless sunlight is caused to fall on a prism (or column of glass whose section is triangular), it is immediately decomposed into seven colors, viz., red, orange, yellow, green, blue, indigo, violet.

Not only may white light be demonstrated by analysis to consist of seven colors, but we can by synthesis show the same fact; for if the beam of light, as it leaves the first prism, is caught on a second prism, equal to the first in all respects, and placed with its base parallel to the edge of the first prism, so that it may act in the opposite manner, it will recombine the colored rays, and produce white light.

The compound nature of white light may be shown in a less perfect manner by mixing together in proper proportion powders of the colors of the spectrum, when a white powder, of a slight grayish tint, is obtained. Another method of illustrating the same fact is to paint the spectrum on a circular disc of pasteboard to which a rapid movement of rotation can be imparted; when the motion reaches a certain rate the colors become blended, and a light grayish tint is produced.

The action of surfaces and media on light is to cause it to undergo reflection, transmission, absorption, interference, or refraction.

1st. Reflection.—When a ray of light falls on a polished surface, it is reflected or thrown back on the opposite side of a perpendicular drawn to the surface at the point of impact of

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Do gases become luminous at the same temperature as solids? Is light simple or compound? How many colors are found in white light? What is a prism? Name the colors produced by the action of a prism on white light. How may the compound nature of light be shown by synthesis? How may the compound nature of light be illustrated by powders? How may the composition of light be shown by the revolving card? What is the action of surfaces and media on light? What is reflection?

the ray. The first is called the incident, and the second the reflected ray. The angle between the incident ray and the perpendicular is called the angle of incidence, while that between the perpendicular and the reflected ray is called the angle of reflection. The law of reflection may be briefly stated as follows:

When a ray falls on any polished surface it is reflected, and the angle of reflection is equal to the angle of incidence.

The amount of light reflected depends on the intensity of the incident ray, the angle of incidence, and the nature of the surface, a polished surface of pure silver possessing far greater reflecting power than a similar surface of iron or other metals.

TRANSMISSION.—If a ray falls on a transparent medium, such as glass, a small proportion is reflected by the surface, while the remaining part is transmitted, or allowed to pass through the medium.

ABSORPTION.—When light falls on rough, dark surfaces, it is absorbed, but not destroyed, for the surface converts it into some other force, as, for example, heat. During the transmission of a ray through a transparent medium a portion of the light is absorbed, so that, in addition to the loss by reflection from the surface, there is also loss by absorption.

INTERFERENCE.—A ray of light may be reflected in such a manner that the waves composing it interfere with each other, the crests of one system corresponding to the depressions of another, and producing darkness. The phenomenon of interference may be illustrated by causing a beam of light to fall on a very narrow slit, and then receiving the rays that pass through the slit on a screen in a dark room. The image formed is not a uniform spot of light, but consists of alternate light and dark lines; the first being produced by the coincidence of crests of waves, the second by the coincidence of crests and depressions.

If a ray is allowed to fall on a ruled surface of steel, glass, or any other suitable substance, the reflected light is decomposed by interference, and a number of spectra produced. The spectrum of interference contains the same colors as the prismatic spectrum, but there is a slight difference in their position; the order of the colors is the same in both, but in the interference spectrum the yellow is in the middle, while in the prismatic

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What are the incident and reflected rays? What are the angles of incidence and reflection? What is the law of reflection? What conditions influence the quantity and intensity of the reflected ray? What is transmission? What is absorption? Is the absorbed ray destroyed? What is interference? How may interference be illustrated? What change is produced in light reflected by ruled surfaces? How does the interference differ from the prismatic spectrum?

spectrum it is in the lower part, the orange and red being compressed, and the violet and blue dilated.

The colors shown by thin transparent substances, as soap-bubbles, and the beautiful tints of certain shells, and such finely-ruled surfaces, are all phenomena of interference.

Refraction.—If a ray falls perpendicularly on a transparent medium with parallel surfaces, it passes directly through it, and continues its course in a straight line; but if it falls on the first surface at any other angle than a right angle, it is bent or refracted from its original track during its passage through the medium, and on emerging from it into the air is again bent, so that the course of the emergent ray is parallel to the track of the incident ray.

If the surfaces of the medium are not parallel to each other, the emergent ray will not be parallel to the incident ray, even though it is perpendicular to the first surface. Advantage is taken of this fact in the construction of prisms, the surfaces of which are arranged at an angle to each other, so as to produce the greatest amount of refraction in a ray.

When a beam of light falls on the first surface of a prism at the proper angle, it is decomposed during its passage through the instrument; and if the emergent beam is caused to fall on a screen placed in the proper position, a spectrum is produced. If we examine the colors in the prismatic spectrum as regards the amount of refraction, we find that the red has been bent from its original course less than the others; it is therefore called the least refrangible ray. The next in order of refrangibility is the orange; then the yellow, green, blue, indigo, violet.

Coloration.—Reflection and transmission may both produce colors by the decomposition of white light; absorption, also, may decompose light. When the absorption is perfect the surface seems to be black; but when certain colors only are absorbed, and the remainder reflected, the surface has the color of the reflected rays. A red surface, therefore, owes its tint to the fact that it has absorbed all the other colors of which light is composed, except the red, which is reflected; the same is the case with the yellow, violet, and other colors. When two or more colors are reflected, the surface possesses the compound tint formed by their union.

What is refraction, and how is it produced? What condition is necessary in order that the emergent ray should be parallel to the incident ray? What is the order of refraction of the different colors of the spectrum, commencing with the least refrangible? Does absorption produce decomposition of light? What is the color of a surface that absorbs light completely? What is the theory of coloration of surfaces?

LECTURE XXXVII.

THE PROPERTIES OF LIGHT.

The three Forces in the Spectrum.—Presence of Heat and its Point of Maximum Intensity demonstrated.—Region of Maximum Intensity of Light.—Action of Yellow Ray on Compounds of Carbon.—Presence of Chemical Rays demonstrated.—Positive and negative Chemical Rays, their Points of Maximum Intensity.—Lenses classified.—Action of convex Lenses.—Of concave Lenses.—Causes of Variation in focal Distance of convex Lenses.—Spherical Aberration described.—Correction of Spherical Aberration.—Chromatic Aberration described, and the Methods of Correction.—Achromatic Lenses.—Penetrating Power of a Lens.—Relation of penetrating Power to the Diameter of a Lens.

We have demonstrated that white light is composed of seven distinct colors; we are now to find that it also contains *heat*, and *chemical* or electrical rays, in addition to the illuminating or *light rays.*

If the spectrum is caused to fall on a blackened surface which has been moistened with alcohol, or some other vaporizable fluid, it is found that the fluid evaporates with the greatest rapidity in the red ray, less in the orange, and least in the violet; we therefore conclude that in the spectrum there are rays of heat as well as of light, and the point of maximum intensity of the heat rays is in the red.

If the spectrum is caused to fall on paper covered with very fine print, we find that the finest print can be read with the greatest facility and at the greatest distance in the yellow ray. The point of maximum intensity of light, therefore, does not correspond to that of heat, but is found in the yellow ray, from which it steadily diminishes to the upper and lower part of the spectrum.

When a spectrum is caused to fall on a row of tubes which have been filled with water, and a portion of grass or some other vegetable substance placed in each of them, it is found that oxygen is evolved with the greatest rapidity in the tube in the yellow ray. The oxygen, under these circumstances, is produced by the decomposition of the carbonic acid dissolved

What are the three forces found in the spectrum? How may the presence of heat be shown? In what part of the spectrum do we find the maximum intensity of heat? How may the maximum intensity of light be shown? Where is it found?

in the water, the vegetable material appropriating the carbon, and setting the oxygen free. Since the action goes on with the greatest rapidity in the yellow ray, it follows that, since the yellow is the region of maximum intensity of light, it is the light, and not the other constituents of the sunbeam, that is engaged in the decomposition of the compounds of carbon; and since that element is the chief constituent of the sensitive coat of the eye, the yellow ray is the most unendurable, and affects that organ with the greatest power.

The presence of chemical rays in the sunbeam may be illustrated by causing the spectrum to fall on a sensitive surface of iodide or bromide of silver, such as is employed in making photographic pictures. When the image is developed in the proper manner, it is found that the deepest stain is produced in the portion which corresponds to the violet ray. The region of maximum intensity of the chemical rays, therefore, differs from those of heat and light, being in the violet.

Not only are chemical rays contained in the spectrum, but, as Professor Draper has shown, there are two classes of chemical rays, the positive and the negative. This fact may be illustrated by causing the spectrum to fall on a sensitive plate which has been previously exposed to a light of moderate intensity. On developing the image, we find that it is longer than when the plate has been carefully protected from the light. The portion of the stain that corresponds to the colors from the yellow to the violet of the spectrum, and beyond, is deeply stained, while that which corresponds to the yellow, orange, red, and the region beyond, is stained to a less degree than the remainder of the plate.

The foregoing experiment demonstrates that in the region of the orange and yellow the action has been the opposite of that in the violet and blue, the first undoing the work of the feeble light to which the sensitive plate was exposed, while the second increases it. In the first the action is negative, in the second it is positive.

Since there are two classes of chemical rays in the spectrum, there are also two points of maximum intensity: that of the positive rays is in the violet, that of the negative rays in the

In which color of the spectrum is carbonic acid decomposed by vegetables with the greatest rapidity? Which force is engaged in the decomposition of carbon compounds? Which ray has the greatest intensity of action on the sensitive coat of the eye? How may the presence of chemical rays in the spectrum be demonstrated? In which color of the spectrum is the chemical force most intense? How may the existence of positive and negative chemical rays in the spectrum be demonstrated? Where are the regions of positive and negative maximum intensity?

red, while in the yellow they both gradually meet, and, destroying each other, produce a region void of action.

LENSES.

There is a great variety in the forms of lenses, but we may reduce them to two classes: 1st. Those which are thickest at the centre; 2d. Those which are thickest at the circumference. The first we shall speak of as convex lenses, the second as concave.

When parallel rays of light fall on a convex lens, they are converged, and, passing from the opposite surface, meet and cross each other at a certain distance from it, forming the focus, from which point they pass on, unless they are intercepted, and become divergent. When parallel rays fall on a concave lens, they diverge on leaving the opposite surface; they never meet, and consequently the lens has no true focus.

The action of a lens may be readily understood by examining the action of prisms on parallel rays. When the ray falls on the first surface at a suitable angle, it is refracted toward the base of the prism without being decomposed; but the angle which the ray forms with the first surface may be so regulated that the ray is both refracted and decomposed, and a spectrum formed.

The first condition is that which exists in a lens, for we may regard a convex lens as being composed of a great number of sections of prisms, so arranged that their bases all meet at the centre of the lens. The action of a prism is to refract the rays toward its base; all the prisms of which the lens is composed therefore refract the rays toward the line passing through the centre of the lens, and, causing them to cross each other at a short distance from it, produce the focus.

In the concave lens, on the contrary, the sections of prisms are arranged so that the bases are at the circumference of the lens; consequently the rays are refracted, so that they recede from its axis and become divergent.

The focus, or point of crossing of the refracted rays that have passed through a convex lens, varies in its distance from the surface. The conditions which govern the distance of the focus

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What is the condition of the chemical rays in the yellow? To what two classes may lenses be reduced? What change does a convex lens impress on rays of light? What is the focus of a lens? What is the action of a concave lens on parallel rays? How may the action of concave and convex lenses be explained? What are the conditions which cause the distance of the focus from the lens to vary?

are, first, the curvature of its surface, and, second, the distance of the object.

In lenses of the same diameter, that which has its surfaces described by the shortest radius, or, in other words, that which is thickest in the centre (providing the circumference in all is equal in thickness), will have the shortest focus; and the less the convexity, the greater is the focal distance of the lens.

The variation of focal distance, caused by variation in the distance of the object, is due to the fact that when the object is close to the lens, the rays emitted from its surface are divergent, while as it recedes from the lens the divergence is less, until finally, at great distances, they virtually become parallel. When the sun's rays are employed to determine the focal distance of a lens, we are dealing with parallel rays; but when an artificial light is used, unless the distance is very great, we employ divergent rays, and the lens has increased work to accomplish in order to bring the rays to a focus; it consequently requires increased focal distance.

In lenses of the same focal distance, those with the greatest diameter give an image which is very indistinct when compared with those of small diameter. This is due to the fact that the different parts of the lens do not bring the rays falling on them to the same focus. It is called *spherical aberration*, and may be relieved by reducing the diameter of the lens by the use of a diaphragm. But it can be corrected by a system of local correction, in which zone after zone of the lens is polished down until all parts have the same focal distance as the central region.

The image produced by an ordinary lens is not only indistinct, but also colored on its edges. This is called *chromatic aberration;* it is corrected by the use of compound lenses, formed of crown and flint glass, ground to fit each other accurately. Though each of these glasses give a chromatic image when used alone, that formed by the compound arrangement is entirely free from color, the error of one lens completely neutralizing that of the other. It is called an achromatic lens.

In lenses of the same focal length, that of the greatest diameter has the greatest *penetrating power*, by which is meant the

Does the lens of the least or the greatest curvature have the shortest focus? How does variation in the distance of the object cause variation in the focal distance of the lens? In lenses of the same focal distance, which will give the sharpest image? What is spherical aberration? How is it produced? How may spherical aberration be relieved? How may it be corrected? What is chromatic aberration, and how is it produced? How is spherical aberration corrected? What is an achromatic lens? What is meant by the penetrating power of a lens? What determines the penetrating power of a lens?

power to define fine lines and discover minute markings. Whenever, therefore, we attempt to correct spherical or chromatic aberration by reducing the diameter of the lens, we reduce its penetrating power. In the correction of chromatic aberration, the same system of polishing concentric zones is followed as was described when treating of spherical aberration, but the difficulties are greater, since there are four surfaces to operate on instead of two.

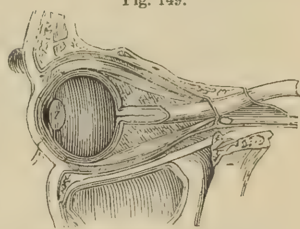
LECTURE XXXVIII.

ANATOMY OF THE EYE.

The Orbits.—Shape and Diameter of the Eyeball.—Its Tunics or Coats. —The Sclerotic.—The Choroid.—The Black Pigment and the Retina described.—The Cornea and the three Humors.—Their relative Density. —The Lens described.—The Hyaloid Membrane and its Function.—The Iris, its Composition and Function.—The Retina and Optic Chiasm.—The Appendages.—Position of the Muscles.—The Conjunctiva.—The Lachrymal Gland and Nasal Duct.—The Eyelids, Glands, and Lashes.

THE eyeball is placed in the orbital cavity, so that it is protected from violence and injury on all sides except anteriorly, and even there is shielded as much as possible by the overhanging brow and hard ring of bone which surrounds the bases of these cavities. The axes of the orbits are in the lower animals very divergent, so as to give them power of seeing laterally to a considerable extent; but in man they are nearly parallel, and directed forward, lateral vision being obtained by the movement of the head on the vertebral column.

Fig. 149.



Position of Eyeball in Orbital Cavity.

The globe of the ball is over one inch in diameter, and nearly spheroidal in figure, the lateral diameter being the shortest. It is composed of three coats or tunics, the sclerotic, choroid, and retina. The sclerotic is formed of dense white fibrous tissue, and gives to the ball its figure and white color; to it the muscles are attached. The choroid is the vascular coat, consisting of arteries and veins, and lined interiorly with black

How does a reduction of the diameter influence the penetrating power? How is the eyeball protected? What is the relation of the axes of the orbits to each other? How is lateral vision obtained in man? What is the shape and diameter of the eyeball in man? Name the three tunics of the ball. Describe the sclerotic. Describe the choroid.

Fig. 150.

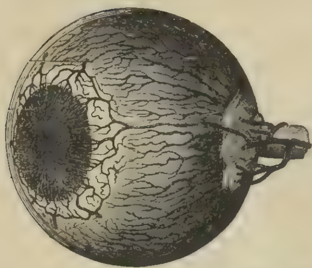
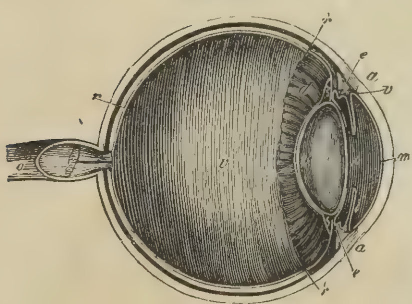


Fig. 151.

Blood-vessels of the Choroid Coat.

pigment. The retina is the nervous coat, and is formed by the expansion of the optic nerve.

Fig. 152.



The Eyeball.

Fig. 152, *a a*, the cornea; *r*, retina; *i*, iris; *e*, lens; *m*, anterior chamber of aqueous humor; *p*, posterior chamber; *d* *r′ r′*, ciliary body; *v*, vitreous humor; *o*, optic nerve.

The organ of vision may with advantage be studied under three distinct divisions: 1st. The optical mechanism; 2d. The nervous mechanism; and, 3d. The appendages.

The optical mechanism consists of the cornea, three humors, the iris, and the screen, or black pigment. The cornea is shaped and fitted into the sclerotic like a watch-glass into its case. It is composed of a transparent fibrous tissue, and serves to give a convex figure to the humor which lies behind it.

The three humors are the aqueous, crystalline, and vitreous. The vitreous is largest in quantity, occupying about four fifths of the bulk of the eyeball; the aqueous is the most fluid, and lies immediately behind the cornea; while the crystalline humor is the densest, and is situated between the aqueous and vitreous humors.

The aqueous humor is divided into two portions by the iris; that which lies between the iris and cornea is called the anterior chamber, and that between the iris and crystalline lens is called the posterior chamber.

Where is the black pigment? Describe the retina. Under what divisions is the eye described? What parts compose the optical mechanism? Describe the cornea. What is its function? Name the three humors. Which is greatest in bulk? Which is most fluid? Which is most dense? What is the relative position of each humor? What are the anterior and posterior chambers?

The crystalline humor or lens is double convex in figure, the posterior surface being the most convex; it is held in position by the ciliary ligament and muscle. The lens is perfectly transparent, and composed of fibres, the edges of which are dentate or serrated, like the toothed edge of a saw; the teeth of adjoining fibres, interlocking with each other, give greater firmness to the lens.

Fig. 153.

Fig. 154.

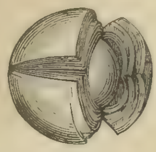
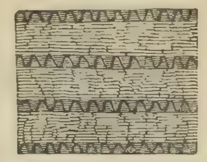


Fig. 155.

Crystalline Lens.

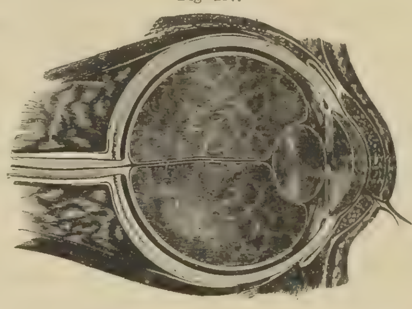
Fig. 156.



Fibres of Lens.

The vitreous humor has a density intermediate between that of the aqueous and crystalline humors; it is held in position, and the formation of currents avoided, by the presence of a delicate membrane, which traverses it in every direction, called the hyaloid membrane.

Fig. 157.



Vitreous Humor, showing the Hyaloid Membrane.

The iris is placed in the aqueous humor, separating it into the anterior and posterior chambers. It is composed of muscular fibres, some of which pass circularly around the central opening or pupil, while the others are arranged as radii, extending from the margin of the pupil to the insertion of the circumference of the iris into the sclerotic. When a strong light falls on the iris the circular fibres contract, and diminish the opening of the pupil.

The black pigment is the inner layer of the choroid or middle coat; it is the screen of the eye, on which the humors bring the images of objects to a focus.

The retina is formed by the expansion of the optic nerve, the portion next the black pigment being the most sensitive. The optic nerves do not pass directly from each eye to the same

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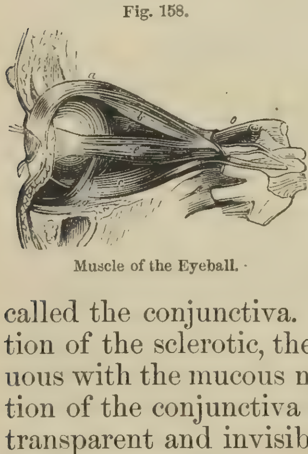
What is the figure of the lens? How is it held in position? What is the composition of the lens? What is the relative density of the vitreous humor? What is the hyaloid membrane? What is the position of the iris? Of what tissue is it composed? How are the fibres of the iris arranged? What is the pupil? Where is the black pigment? What is the retina? Which part is the most sensitive?

side of the brain, but they meet at a short distance behind the orbits to form the optic chiasm, in which there is a crossing and interchange of nerve fibres, so that a portion of those from the right eye pass to the same side of the brain, some to the left hemisphere, and others to the left eye. Those from the left eye pass to the left and right hemispheres, and to the right eye. There is, consequently, a perfect and free communication between the eyes, and any cause which affects one eye is almost certain to produce disturbance in the condition of the other.

The appendages of the eyeball are muscles, an exterior mucous membrane, the lachrymal apparatus, the lids, eyelashes, and eyebrows.

The muscles of the ball are six in number; four pass from the apex of the orbital cavity to be inserted into the upper, lower, inner, and outer parts of the ball: they are called the recti muscles, and are designated respectively as the internal, *f*, external, *e*, superior, *b*, and inferior, *c*, rectus. The other muscles pass obliquely from the sides of the orbit, and are known as the obliquus superior and inferior, *g*, while the muscle which raises the upper eyelid is called the levator palpebræ, *a*.

Fig. 158.



Muscle of the Eyeball.

The mucous membrane of the eye is called the conjunctiva. It covers the cornea, the anterior portion of the sclerotic, the inner surface of the lids, and is continuous with the mucous membrane of the nasal cavity. The portion of the conjunctiva that passes over the cornea is perfectly transparent and invisible, except when the vessels are injected by inflammation.

The lachrymal apparatus consists of the lachrymal gland, its ducts, and the nasal duct. The gland is placed in the upper and outer part of the orbit, and furnished with a number of small ducts, by which the secretion is delivered on the conjunctival membrane of the ball. The nasal duct commences at the inner angle of the eye, and terminates in the nasal cavity.

What is the optic chiasm? What disposition is made of the nerve fibres from the retina of the right eye—from the left eye? What are the appendages of the eye? How many muscles are attached to each eyeball? Give the position of each of the recti muscles. What are the oblique muscles? What is the name of the mucous membrane of the eye? What parts does the conjunctiva cover? What is the effect of inflammation on the transparency of the conjunctiva? What parts compose the lachrymal apparatus? Where is the lachrymal gland? How is its secretion delivered on the conjunctiva? Where is the nasal duct?

The lids are composed of skin externally, and mucous membrane internally. The upper lid is provided with a disc of cartilage, which gives to the lid its figure. On the edge of both lids there is a row of glands, which are placed between the hairs or lashes of the lids; inflammation of these glands is very common, and is generally known as sty.

The eyebrows are formed of short hairs, which are arranged in such a manner as to direct the perspiration as it flows down the forehead on each side, and prevent its passing into the eyes and interfering with vision.

LECTURE XXXIX.

THE ACTION OF THE EYE.

The Function of the three Humors.—The Action of the Iris.—Adjustment for Difference of Distance of different Objects.—Method of Correction of Spherical Aberration.—Correction of Chromatic Aberration.—Action of black Surfaces on Light.—Action of the Ocellus.—Action of the Compound Eye of a Fly.—Action of the Eye in the Higher Animals.—Action of the Muscles of the Eye.—Of the Lachrymal Apparatus.—Of the Lids, Lashes, and Eyebrows.—Longsightedness and Shortsightedness described.—Method for relieving them.—Cataract described.—Operations for its Relief.—Strabismus.—Peculiarities of the Optical Apparatus in the Lower Animals.—Constitution of Areolar Tissue.—Adipose Tissue, its Formation, and Tenacity of certain Positions.—Description of the Skin.

The action of the eye may be studied under three divisions: 1st. That of the optical portion; 2d. Of the nervous portion: and, 3d. Of the appendages.

The humors of the eye, taken together, form an achromatic combination, which brings the rays falling on the cornea to a sharp focus on the black pigment.

The iris regulates the quantity of light passing into the interior of the ball. When the light is intense the pupil contracts, and when it is feeble it expands, so allowing a greater or lesser number of rays to enter the organ.

The adjustment for variation in the distance of various objects is accomplished by the ciliary muscle and ligament, which alter the distance of the lens from the black pigment, and also change its curvature by compressing it at the circumference.

What is the composition of the eyelids? Where are the glands of the lids? What is sty? What is the function of the humors of the eye? What is the action of the iris? How is the adjustment for variation in the distance of objects obtained?

The correction for spherical aberration is accomplished by the varying density of the different parts of the lens, and the contraction of the iris, which reduces the diameter of the beam of light entering the eye.

In order to understand the function of the nervous mechanism, we must first examine the action of black surfaces on light. Franklin found that if small pieces of cloth, of various shades of color from white to black, were placed on snow on a clear winter's day, they absorbed the sunlight, and melted their way to different depths in the snow. The colors he used were black, dark blue, pale blue, green, purple, red, yellow, and other shades, up to a pure white. In a short time the black had passed out of reach of the sunlight; the dark blue was almost as deep in the snow, and the others had sunk to a less extent as their color was lighter, the white cloth remaining on the surface. Sir Humphrey Davy made a similar series of experiments with pieces of colored copper, each one inch square, and of the same weight and density; one was black, one blue, one green, one red, one yellow, and one white. On the middle of the under surface a small portion of a wax cement, that melted at 76°, was placed. The strips were then placed on a piece of board painted white, and exposed equally to the direct rays of the sun. After a short time the wax on the black plate commenced to melt, and the others followed in the order in which they have been mentioned; but the white strip showed no tendency to melt its wax until that on the black one was entirely fluid.

In the lowest grades of animal life, we find that the ocellus, or minute eyes of animalcules, consist of a nerve which terminates in a loop covered with black pigment. In such creatures, the light, falling on the ocellus, is converted into heat, and the animal feels its way to the side of the vessel which is most perfectly illuminated, or hides in some dark recess to rest, its movements being guided by the variation in the temperature of the ocellus.

Passing a little higher in the scale, we reach the compound eyes of insects, such as the fly, in which the cornea is composed of a vast number of small hexagonal corneæ, which are the bases of an equal number of cones, the apices of which meet at the optic nerve. A filament of the nerve passes into the apex

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How is spherical aberration corrected? Describe Franklin's experiment. Why did the black pieces of cloth sink to the greatest depth? What is the simplest form of eye? How does the ocellus act? Describe the compound eye of the fly. How does it act?

of each cone, and is covered with black pigment, so that the creature can not only feel the presence of the light, but can also determine its direction, and the outline of the luminous object.

In the perfect eye of the highest grades of animals the principle of action is the same. The optical mechanism brings the rays to a focus on the black pigment, where the image of light is converted into a heat picture, and, as such, felt by the terminal tubes of the optic nerve, which abut in infinite numbers against the black pigment, and, passing to the brain, convey to it the impressions they have received in the pigment.

The appendages may be divided into the motive and protective. The first give to the ball its movements, the recti directing it respectively upward, downward, to the right, and to the left. The oblique muscles rotate it on its axis, and aid in giving to the eye the variable expression of which it is capable.

The lachrymal gland furnishes the moisture which preserves the conjunctiva in a transparent state. The secretion is equally diffused over the anterior surface of the eye by the lids first touching at the outer angle, so as to sweep the fluid furnished by the gland over the surface of the ball, and wash all dust or other foreign substances to the inner angle, where they are conveyed by the nasal duct to the nasal cavity.

The eyelashes aid in protecting the eye by causing the sudden closure of the lids when any object touches them; the eyebrows, as we have previously stated, direct the perspiration as it flows down the forehead, and prevents its passing into the eyes.

Of the diseases which affect the eye, none are of greater interest than long and shortsightedness. The first exists in old, and the second in young people. In the earlier period of life, the humors of the eye, as well as all the tissues of the body, are distended with moisture, consequently the ball is bulged forward, the convexity of the cornea increased, and the focus of the eye shortened, so that the image falls in front of the black pigment; the object must therefore be approached close to the organ in order to throw the focus backward, and produce a sharply-defined image on the pigment. In old age, on the contrary, the humors are deficient in quantity, the ball is less dis-

What is the method of action of the eye in man and the highest grades of animals? What is the function of the recti muscles? How do the oblique act? What is the use of the lachrymal secretion? Where do the eyelids touch first? How is the lachrymal secretion finally disposed of? What is the function of the eyelashes? What is the object of the eyebrows? At what period of life does longsightedness appear? When does shortsightedness occur? What is the cause of shortsightedness—of longsightedness? Where does the focus fall in shortsightedness?

tended, the cornea flatter, and the focus falls beyond or behind the black pigment; the object must consequently be placed at a greater distance from the eye, in order to bring it to a sharp focus on the pigment. This condition is therefore called longsightedness.

Shortsightedness may be relieved by the use of *concave* lenses, which cause the rays to diverge as they enter the organ, and so throw the focus farther back; longsightedness, on the contrary, requires the use of *convex* lenses, which converge the rays, and, bringing the focus forward, cause it to fall on the pigment. In the selection of glasses, the lens for each eye should be chosen separately, for there is usually a difference in the foci of the eyes; and if lenses of the same focus are used under such conditions, one eye is apt to be strained, and more or less injury of the organ produced.

The various tissues of the eye are liable to rheumatic, ordinary, and specific inflammations, which should be immediately placed in the care of an experienced physician; for it is to be remembered that the eye is very delicate, and inflammation, especially when produced by some specific cause, is apt to result in its sudden destruction.

In certain families there is a predisposition to the formation of an opacity of the lens, called cataract, in which it becomes perfectly opaque, and the passage of light to the interior of the eye being cut off. As long as the disease exists in one eye only, it is best to let it alone; but when it exists in both lenses, and useful vision is lost, an operation may be performed, which, in the majority of cases, results in affording the patient a very fair degree of vision.

The operations for cataract consist in either passing a suitable instrument through the cornea, and depressing the opaque lens out of the axis of vision, or in making an incision in the cornea, through which the lens is extracted. Inflammation is, of course, produced, and loss of both eyes may follow an operation on one. Such treatment ought, therefore, never to be adopted until all useful vision is lost.

Squinting, or strabismus, is caused by an undue contraction of the external or internal rectus muscle; it may be relieved by catching the muscle on a suitable hook, drawing it forward,

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Where does the focus fall in longsightedness? What class of lenses are required in shortsightedness? How do they act? What lenses relieve longsightedness? How do they act? Why should the lenses be chosen separately for each eye? What is cataract? How does it produce blindness? Under what circumstances should an operation be performed? Describe the operations for cataract. What is strabismus? How may it be relieved?

and severing it with a pair of scissors. The operation is not always successful, for the eye is sometimes turned in the opposite direction.

The lower animals present various peculiarities as regards the eyes, among which we may mention the chameleon, in which the eyes are placed on stems or stalks, and are capable of independent motion. In the carnivora the eyes are very large compared with the size of the animal, and the exterior wall of the orbit is composed of ligament, which allows the eyeballs to be pressed outward, giving to the creature a peculiarly ferocious look. In the herbivora, on the contrary, they are small, as in the elephant. In the burrowing animals, as the mole, they are very minute, and in fishes which inhabit the waters of caves they are reduced to a rudimentary condition. In birds there is a third eyelid, which passes transversely across the eye, to which the name of membrana nictitans is given.

In enumerating the organs of the body, the areolar or connective tissue, and the skin, were mentioned. The areolar tissue is composed of yellow elastic and white inelastic fibres, which interlace with each other in every direction, to form a tissue filled with areolæ or spaces.

Fig. 159.

Cellular Tissue.

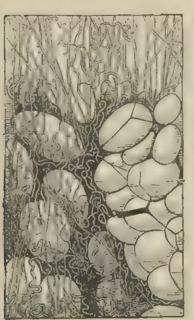
When the areolar tissue is employed for the purpose of connecting muscles or retaining organs in their proper position, it is loosely woven, so that the areolæ, or cells formed by the fibres, are of considerable size; but when it is employed to form membranes, it is then closely woven, and the cells or spaces disappear.

The connective, or, as it is often called, cellular tissue, lies between all the muscles and organs of the body, and there is a perfect communication among the spaces or cells, as is demonstrated by the fact that when the ribs are fractured, and the lung wounded so that the air passes into the cellular tissue, it quickly finds its way between all the organs of the body, and

What is the peculiarity in the eyes of the chameleon? How do the eyes of the carnivora compare in size with the herbivora? What gives to the carnivora their ferocious appearance? What is the peculiarity in the eyes of burrowing animals like the mole? What is the membrana nictitans? What is the composition of areolar tissue? Under what circumstances does the texture of connective tissue vary? How is the communication of the cells of areolar tissue demonstrated?

the areolæ or spaces become filled with the gas, and the body distended to an unnatural and dangerous degree, so that incisions in the skin have to be made in order to relieve the sufferer.

Fig. 160.



Adipose Tissue.

In the cells of the areolar tissue fat globules are deposited, forming the fatty or adipose tissue. By this device provision is made for a very considerable deposit of fat, without interfering with the action of any organ. There are, however, certain localities in which fat remains in considerable quantity, even to the last point of starvation; among these we may mention the orbits as most prominent, a certain proportion being required to form a cushion for the eyeball, in order to give it proper support.

The skin we have already described in part when speaking of the organ of touch. It consists of two layers, the external epidermis or cuticle, formed of epithelial cells, which are worn away by contact with hard external substances: it is reproduced from the inner layer, called the cutis vera (true skin), or derma.

The derma is composed of areolar tissue, blood-vessels, nerves, glands, and hair follicles, all of which have been described in previous lectures. The function of the skin is to form an external covering to the tissues of the body, and protect them from the action of air, water, and external violence, while the areolar or connective tissue holds each organ in its proper place, and retains the skin in contact with the tissues it protects.

How is fatty or adipose tissue formed? Of what part of the body is the fatty deposit most tenacious? Of what parts is the skin composed? Describe the derma. What is the function of the skin?

SECOND DIVISION.

DYNAMIC PHYSIOLOGY.

LECTURE XL.

REPRODUCTION.

Reproduction of Plants. — Conditions requisite for Germination and Growth.—Reproduction of Animals.— Organs of Reproduction in Oviparous and Viviparous Animals.—Menstruation.— Corpus Luteum.—Semen, its Composition and Properties.—Impregnation.—Nourishment of Fœtus.— The Placenta.— Quickening.—Miscarriage.—Parturition.—Change in Respiratory Function at Birth.

HAVING completed the study of man as an individual, we now pass to the second division of Physiology, which Professor Draper has specified as Dynamic Physiology. In this branch the phenomena of reproduction are of special importance; we shall, therefore, first devote as much space as possible to their consideration.

Plants are reproduced either by the ordinary reproduction of cells, or by inflorescence and the formation of seeds. Flowers are of two kinds, male and female. The first forms a fine, dust-like powder called pollen, which is brought in contact with the seed vesicles of the female flowers either by the winds or through the agency of insects. Without the access of the pollen the female flowers are sterile, and neither fruits nor seeds are produced.

During the inflorescence of plants a considerable amount of heat is evolved, and carbonic acid at the same time produced, so that there are periods in the life of a plant when it takes on an action similar to that in animals, becoming an oxidizing instead of a deoxidizing agent.

When the perfect seed is produced, its vitality is dormant until it is placed under proper conditions for development into a plant. These are moisture, air, warmth, and darkness; but

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How are plants reproduced? What is the pollen? What is its function? What is the effect of inflorescence on the temperature? What gas is produced during inflorescence? What conditions are required for the development of a seed? What are the conditions required for healthy growth in a plant?

the moment that it has fairly sprouted it requires a free exposure to light in order to develop in a proper manner, and produce green leaves, and the gum, and other materials out of which the tissues of plants are constructed.

Fig. 161.

Hydra budding.

Among animals, many of the lowest forms, such as the hydra, are reproduced by germination, or budding, a new creature sprouting from the side of the parent, and being detached as soon as it has reached a sufficient degree of perfection to take care of itself.

The great majority of animals, like plants, originate in the conjunction of male and female germs, the female furnishing a suitable ovum or egg, which must be vivified by the male, in order that it may develop into a perfect form resembling one of the parents.

If the female retains the ovum within her body until it is perfectly developed into a living representative of its species, and then brings it into the world alive, it is said to be viviparous. If, on the contrary, the embryo is ejected in an imperfect form, as an egg, which has to be subjected to the influence of elevation of temperature for a given period before a living creature is produced, it is called oviparous.

In the oviparous class the testes of the male are usually inclosed within the body, and the female is provided with an ovary and an ovipositor, in which the egg receives its external hard coating or shell.

In the viviparous animals the testes of the male are exterior to the body, and placed in a suitable envelope of skin called the scrotum, while the female is furnished with a pair of ovaries, and a uterus or womb, in which the embryo is retained until it is perfectly developed, and able to live and move about freely. For the proper nutrition of its young the female is farther provided with mammæ or teats, which furnish milk suitable for the wants of its offspring.

In both oviparous and viviparous animals, the appearance of the power of reproduction marks the end of the period of growth, very few animals commencing to reproduce their species until they have themselves reached a perfect state of development. In the lower animals the appearance of the repro-

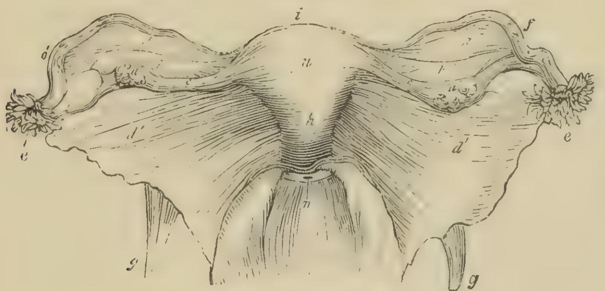
Describe the methods of reproduction of animals by germination. How are animals generally reproduced? What is meant by viviparous and oviparous animals? What is the position of the testes in the oviparous creatures? Where does the egg receive its shell in the oviparous female? What organs form the reproductive apparatus in the viviparous female? At what period of life does the power of reproduction appear?

ductive period is marked by the condition called *heat*, which comes on, in the majority of the higher animals, once or twice in the course of the year; but in small animals, which are not provided with any effectual means of defense, it occurs more frequently.

In the human female this condition is called menstruation, and it occurs in healthy women regularly every four weeks. It is marked by congestion of all the organs connected with reproduction, including the mammæ, and the discharge from the uterus of a sanguineous fluid.

At each menstrual period an ovum is discharged from the ovary, *a a*, which is, in the human female, attached to the lateral ligaments *c c*, that holds the uterus, *u*, in its proper position in the pelvic cavity. The uterus is provided with a singular

Fig. 162.



Uterus and Appendages.

apparatus on each side, called the Fallopian tube, *f o′*, which terminates in a free fimbriated extremity, *e*, that curves over toward the ovary, and, grasping it at the time the ovum is discharged, conveys it into the cavity of the womb. In *Fig.* 162, *d d*, *d′ d′*, *g g*, are other ligaments of the womb; *h* is its neck; *n*, the opening or os uteri, the letter being placed on the upper part of the vagina.

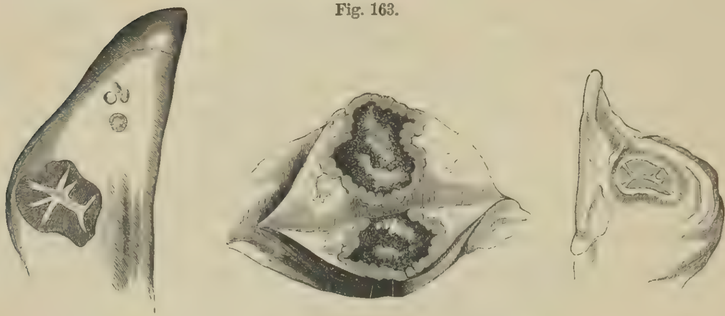
The escape of an ovum from the ovary causes a wound, which gradually heals and leaves a scar, which remains during life if the ovum is impregnated, and is called the corpus luteum.* If the ovum is not impregnated the scar gradually disappears, and while it exists is called a false corpus luteum.

When it has reached the uterus the unimpregnated ovum is discharged, together with blood, epithelial cells, and the secre-

* See Dr. J. C. Dalton on Corpus Luteum.

What is meant by *heat* in animals? How often does it occur? What is menstruation? Where is the ovary in the human female? What is the Fallopian tube? What is the corpus luteum?

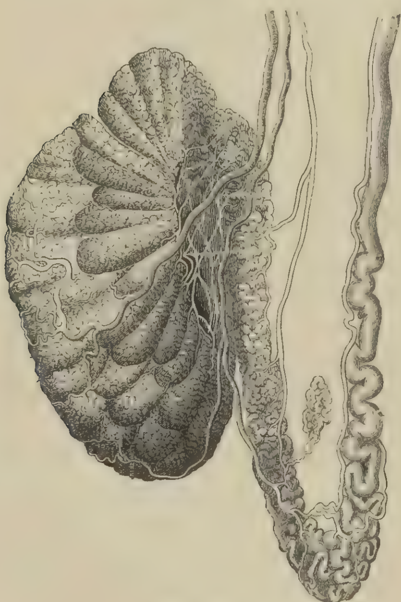
Fig. 163.



Corpora Lutea.

tions of the parts. The menstrual fluid differs from ordinary blood in that it does not form a coagulum or clot, unless there is a great excess of blood in the secretion.

Fig. 164.



The Testis.

In the male the germs are prepared by the testes. The fluid formed is called semen, and consists of an albuminous liquid, in which minute cells, called spermatozoa, are in active movement. The spermatozoon is a caudate cell, shaped like a tadpole with a long tail; it is about $\frac{1}{10000}$th of an inch in width, and $\frac{1}{500}$th of an inch in length, and continues to move about vigorously as long as it retains life.

From the fact that the corpus luteum produced by an impregnated ovum is different from an ordinary false corpus luteum, it is probable that the vivification of the ovum occurs before it leaves the ovary, so that the spermatozoa must find their way through the uterus and Fallopian tube in order to accomplish that result.

Leaving the ovary, the impregnated ovum passes slowly down the Fallopian tube to the uterus, and is attached to its

How does the menstrual fluid differ from ordinary blood? What is semen? Describe the spermatozoa. Where is the ovum impregnated? What facts show that impregnation occurs in the ovary? Describe the course of an ovum after it is impregnated. How is the ovum disposed of on reaching the uterus?

walls near the opening of the tube. It steadily increases in size until a sac filled with fluid is formed, on one side of which the embryo commences to assume its proper figure.

In the earliest stage of development, the materials for the nutrition of the embryo are obtained from the yolk of the ovum, but soon after it reaches the cavity of the uterus it derives its nutriment from tuft-like vessels which attach themselves to the wall of the womb. These finally become consolidated, forming a distinct organ called the placenta, by means of which the fœtus (as the child in utero is called) is nourished until the time of birth.

With the increase in the bulk of the fœtus, the uterus gradually rises out of the pelvic cavity, and toward the close of the period of gestation occupies the abdominal cavity, interfering seriously with all the functions of the system.

Quickening, or the first movements of the child, are noticed in the eighteenth week, and delivery occurs about 280 days from the time of impregnation. This is, however, liable to variation, children being often born in an imperfect condition by a miscarriage. If the child is in the eighth month it will live, and seven months' children have been often successfully reared. Some women carry their children longer than forty weeks, and, according to the French laws, a child is legitimate if born within 300 days.

The act of parturition commences with slight contractions of the fibres at the base of the uterus, while those at the mouth and neck are relaxed. After a short time, the membranes which form the water-cushion on which the fœtus rested are ruptured, the waters escape, and the child is born, the head being usually the first part to come in contact with the external air.

The contact of the body of the child with the air seems to cause pain, for it gives utterance to a cry, which marks the first entrance of air into its lungs. At the same time, the flow of blood is directed from the placental vessels to those organs, and respiration is in a moment changed from the aquatic to the aerial form.

How is the embryo nourished in its earliest stages? What is the placenta? What is the position of the uterus at the close of the period of gestation? What is quickening, and when does it occur? What is a miscarriage? What is the French law regarding legitimacy? What is parturition, and how is it conducted? What part of the child is usually born first? What is the effect of the contact of air with the body of the child? How is the function of respiration changed at birth?

LECTURE XLI.

THE COURSE OF HUMAN LIFE.

The five Periods in the Life of an Individual.—Size of the new-born Infant.—Rate of Growth.—Average Height of Adults.—Maxima and Minima of Height.—Weight at Birth.—Average Weight of Adults.—Period of maximum Weight.—First Attempts at articulate Speech.—Relation of the vegetative and intellectual Powers to each other.—Evidences of their Influence on each other.—Decline of Intellectuality.—Average Duration of Life.—Mortality at different Periods.—Influence of Sex and Stature on Mortality.—Instances of great Longevity.—Approach of Death.—The Facies Hippocratica.—Interstitial Death.—Period of Repair.—Sleep.—Amount of Sleep required at different Periods of Life.—Order in which Sleep subverts the Senses.

The life of man may be divided into five periods: 1st, the fœtal; 2d, the infantile; 3d, the adolescent; 4th, the adult; and, 5th, that of old age. The first period we have examined in the previous lecture as far as our space would admit; we therefore now pass to the consideration of the infantile period.

The average length of the newly-born male infant is 18½ inches, while that of the female is 18⅛. During the first five years the annual rate of growth is rapid; but it gradually becomes less and less, until a uniform annual rate is established of about 2⅕ inches, which continues from the fifth to the sixteenth year; in the seventeenth year it is about 1½ inches, and during the eighteenth and nineteenth about one inch.

The full growth is usually attained at about the age of twenty-one, but many persons continue to grow to the twenty-fifth year. The average height of an adult, according to Quetelet, is 5 feet 8 inches. He also states that the maximum is 8 feet 3 inches, and the minimum 1 foot 5 inches.

At birth boys are heavier than girls; the average weight being 6¼ lbs., the maximum 12½, and the minimum 2¼ lbs. During the first week of infantile life the weight diminishes slightly, owing to the change to the aerial form of respiration; it then increases rapidly, tripling in the first year, doubling that

What are the five periods in the life of an individual? What is the length of a new-born infant? At what period is the rate of growth most rapid? What is the rate from the fifth to the sixteenth year? At what age is the full growth attained? What is the average height? What are the maxima and minima of height? What is the average weight at birth? What are the maxima and minima of weight at birth? What change occurs during the first week of infantile life?

in the following six years, after which the rate becomes less and less, the maximum being reached at the fortieth year; it then remains nearly stationary until the sixtieth year, when it commences to diminish until death.

The average weight of men between 25 and 40 is about 140 lbs., and of women 120 lbs.: the healthy maxima and minima in men are 216 lbs. and 108 lbs.; in women, 206 lbs. and 87 lbs.

As the human being develops in stature and weight, the intellectual powers also increase in perfection. At its entrance into the world, there is no other mammal so utterly dependent, so weak, and void of intellectual power as an infant. The organs of special sense seem to be perfectly developed, but they are not employed, and the future hero lies in his cradle a helpless mass of imbecility, scarcely showing his existence save by cries of pain, and spending his days in eating and sleeping.

Gradually, as it increases in size and weight, the infant begins to obtain the use of its special senses, and, overcoming the state of stupefaction produced by the numberless objects it met on its entrance into the world, it commences to recognize those by whom it is surrounded, and rewards the anxious care of its mother with sunny smiles.

During this early period life is absolutely vegetative, but at about the twelfth or eighteenth month the infant commences to gain the power of articulate speech, which seems to mark the epoch at which the mind obtains the ability to concentrate itself on one object or sensation. As the age advances the intellectual power rapidly increases, until at the period of puberty it predominates over the vegetative life, which up to that time is in the ascendant.

The mental and intellectual powers reach their zenith at about the fiftieth year. They are most intimately connected with the physical condition of the body, and the reaction of the mental and animal individualities on each other are demonstrated by the facility with which we select the intelligent from the imbecile by the expression of their faces, or read the thoughts and ideas which illuminate the countenance before they assume the form of speech.

When is the maximum of weight attained? When does the period of decline commence? What is the average weight of adults? What are the maxima and mimima? What is the condition of the new-born infant? At what period is the power of articulate speech gained? What change in the mind occurs at the same time? What is the relation of the vegetative to the intellectual powers at the different periods of life? At what age does the intellect reach its maximum? What are the evidences of the influences of the physical and intellectual powers on each other?

As soon as the intellect has reached its maximum the period of decline commences, and not only the special senses, but also ideality and reason, begin to fail, the passions lose their intensity, ambition its sway, and as old age gradually steals upon the great statesman or humble laborer, they fall alike into the same condition of mental imbecility which they presented on their entrance into the world, every species of exertion becoming irksome, memory more and more obtuse, the last acts of an eventful life being the first to fade away, until at last only the recollections of the associates and joys of childhood are retained, and the child of a hundred years dozes quietly and dreams away his life, waiting for the death-sleep to close his eyes forever.

The average duration of life is about 33 years, the mortality being greatest in its earlier period. About 22 per cent. of the births are lost before they reach the close of the first year, and 37 per cent. before they reach the sixth, and at twenty-five half the births are lost.

The ratio of mortality is greater in cities than in the country; it also increases among females between 14 and 18, and during the period of child-bearing, and among men between 21 and 26. Stature also possesses an influence, tall men generally being short-lived.

Geographical position causes a variation in the ratio of mortality, being 1 to 41 in Northern Europe, 1 to $40\frac{8}{10}$ in Central Europe, and 1 to $33\frac{7}{10}$ in Southern Europe. The greatest number of old people is found in the temperate zone, which furnishes also the largest proportion of recorded instances of longevity, of which the following may be mentioned as being well authenticated: Margaret Patten, 137 years; Thomas Parr, 152; John Room, 172; Peter Torton, 185.

The following tables show the proportion of persons in different communities that reach the age of 100 years, and also the average mortality in some of the great cities:

Number who are 100 and upward in a population of 20,000:

England	0·34
Wales	0·50
United States, freemen	1·02
" " slaves	14·10

When does the intellectual power begin to decay? Do the impressions of the earlier or later period of life fade first? What is the average duration of human life? At what period is the mortality greatest? What proportion of births are lost at the close of the first year? What at the sixth—the fifteenth—twenty-fifth? What differences exist in the ratio of mortality in the different sexes? What is the influence of stature on the rate of mortality? What is the influence of geographical position? Mention some of the instances of the greatest longevity.

	Mortality one in		Mortality one in
England	51	Charleston	37
Wales	69	Berlin	34
Philadelphia	46	Paris	32
Manchester	44	Naples	28
London	40	Rome	25
New York*	38	Vienna	23

The longest life must at last terminate, and every one must sooner or later pass over the bridge of death to join his forefathers in the unknown land. We instinctively shrink from the final act, and speak of it as the agony, dreading it not so much on account of the pain suffered as of the gloom and solemnity of the grave, and the uncertainty attending our fate in the night of eternity.

Death rarely comes to us by the slow approaches of old age; his onslaught is sometimes sudden, and life is overwhelmed before the approach of danger is even suspected. In such a violent, sudden physical annihilation there can be but little pain, for the face of the soldier who has been cut down in a moment bears the expression that was flitting across it at the time the fatal bullet touched the vital spot, and retains even in death the impress of the exultation of victory or the despair of defeat.

Excepting the comparatively small number of instances of death by accident and old age, we may regard it as usually occurring from disease, which is more or less prolonged, so that the powers of life are wasted, and sensations and senses dimmed before dissolution commences. The approaching termination of the sufferings of the dying man have been so well portrayed by the pen of Hippocrates that even modern science accepts his description as being unsurpassed, and gives to the peculiar physiognomy of death the designation of the "Facies Hippocratica." It is ushered in "by the patient showing a disposition to lie on his back, his arms stretched out, his legs hanging down, and a tendency to slide down in the bed. The motions of the hands are sometimes uncertain, and the patient picks at the bedclothes as though he was attempting to remove small objects from them; the countenance is changed; the lips hang relaxed and cold; light becomes unbearable; the brightness of the eyes is lost, and they become overspread with a misty cloud; the balls shrink into their sockets; the nose is sharp-

* One cause of the greater mortality of New York is the enormous number of emigrants arriving at that port.

How does death usually make its approach? What is the Facies Hippocratica? Describe the symptoms and movements that attend the approach of death.

ened; temples hollow; ears cold and white; and the features pinched, and of a greenish or lead-colored hue."

Though death is generally regarded with such intense feelings of repugnance, it is nevertheless essential to the well-being of all living creatures, for the processes of life can not be accomplished without the continual destruction of the tissues composing the body. To these phenomena the designation of interstitial death has been given: it commences with the first breath and continues throughout life, but is repaired as fast as it occurs by the organs of nutrition. During the early periods of life repair is more rapid than waste; the body consequently increases in size and weight, until finally an equilibrium is reached, which lasts for a few years, when the weight commences to decline, the waste being more rapid than the repair in the systems of old people.

Reparation of tissues take place chiefly during sleep. In infancy and adolescence, when the body is growing rapidly, the greatest portion of our time is spent in sleeping, so that the construction and increase of tissues may advance with as little interruption as possible. When the adult period is reached, the average amount of sleep is about eight hours in every twenty-four, though many people need only four or five, or even less. As old age approaches, and the recuperative powers of the system decline, a far greater amount of sleep is required.

The approach of sleep is marked by the gradual loss of vision, then the sense of smell is blunted, hearing becomes more and more obtuse, the sense of touch is obscured, the muscles are relaxed, and the pulsations of the heart and the respiratory movements become less rapid and more regular. The deepest sleep is in the earliest part of the night, and it gradually becomes lighter on the approach of day, when the mind regains its consciousness in the reverse order to that in which it was lost.

When the system does not obtain a sufficient amount of sleep, either on account of care, anxiety, or overwork, the great nervous ganglia become irregular in their action, the functions of the body are disordered, digestion is imperfect, and the tone of all the organs and tissues steadily declines. But an over-indulgence in sleep is almost equally injurious, for the nervous

What is interstitial death? At what time does repair take place most rapidly in the system? At what period do we sleep most? What is the average amount of sleep required by adults? Why do old people sleep so much? What is the order in which the senses are subverted by the approach of sleep? At what time is sleep the most profound?

system becomes less sensitive, the moral and intellectual faculties are blunted, and all the functions of the system are conducted in an imperfect manner, and some even think that continued over-sleeping will produce such serious diseases as lunacy and idiotcy; but it is probable that in such cases the tendency to oversleep is merely a symptom of the approach of the disease.

LECTURE XLII.

INFLUENCE OF EXTERNAL AGENTS ON THE PHYSICAL AND INTELLECTUAL CONDITION OF MAN.

Distribution of Plants.—Conditions which Control their geographical Position.—Nature of the Boundary-lines formed.—Influence of Ocean Currents on Climate.—Distribution of Animals.—Influence of Physical Agents on Man.—Theories regarding the Origin of the Human Race.—Explanation of the Production of Races.—Variation in the Color of Men.—Measurements of the Skull.—The Facial Angle.

It is a well-known fact that different vegetable products are found on different parts of the earth's surface. The conditions which control the distribution of plants are chiefly heat and moisture; and, by examining into the causes which influence these conditions, we find that there is not a single physical agent that does not possess more or less power in determining the geographical distribution of every species of plant.

If we trace on the globe the lines which mark the limits of growth of any plant, we find that they do not follow the parallels of latitude, but pass above and below them to an extent equal to ten or even twenty degrees. These curves are partly due to the influence of variation in elevation of the surface above the level of the sea, but chiefly to winds and the currents in the oceans, which convey enormous masses of warm water from tropical to northern regions, and modify the temperature to such an extent as to produce a climate milder than that of other countries which are much farther south, but do not enjoy the same advantages.

The conditions which influence the distribution of plants also determine that of animals, confining them to certain localities, beyond the boundaries of which they can not pass but at

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What are the conditions that control the distribution of plants? What is the nature of the lines that bound the distribution of various plants? What are the agents that produce these curvatures? How do the ocean currents modify climate?

the risk of destruction from various physical agents. Certain species are more widely scattered than others; but they are few in number, and are almost all included in the list of creatures which are domesticated by man, either for purposes of pleasure or profit.

As physical agents determine the characteristics and distribution of plants and animals, so also they influence the peculiarities and distribution of man, changing the tint of his skin, altering the shape of his skull and features, and influencing his habits and mental qualities to such an extent as to produce a number of races that differ so widely in their characteristics as to have given origin to the doctrine that all men have not been produced from one original pair, but that there have been a number of different points of origination corresponding to the different races or types of men.

The two theories of the Unity and the Diversity of Origin have numerous and influential supporters among the highest intellects, but the majority of savants accept the doctrine of the unity of the race, which is by far the most natural and probable, explaining the differences that exist by demonstrating that they are produced by the action of external physical agents.

One of the most striking differences is the variation in the color of the skin, that of the inhabitants of tropical regions being olive-colored or black, while, as we pass northward, it becomes lighter, until finally, in the temperate regions, it is white, or of a pale pink tint. The best illustration of the influence of temperature on color is afforded by the Jews, who, though scattered among all the nations of the earth, have preserved their national type intact by continuing to intermarry among themselves; yet their color varies with the locality they inhabit, some being as white as the pure-blooded Caucasian, while others, who lived in tropical climates for many centuries, are black, but preserve the Jewish features unaltered.

The change in color of a race requires many generations for its accomplishment, but there are other characteristics of the different types which are more profound in their nature, and therefore necessitate the lapse of a far longer period of time to affect them; among these are the peculiarities in the figure of the skull, and variations in the size of the cranial cavity and

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What species of animals are most widely distributed? Is man subject to the influence of physical agents? What are the two theories regarding the origin of the human race? Which is most generally received? How does the theory of the unity explain the production of races? Give an illustration of change in color due to external physical agents. What other characteristics of race exist besides color?

brain, which determined, to a certain extent, the intellectual power.

Skulls are measured by two methods, one of which consists in filling the cranial cavity with shot or peas, and pouring the contents into a measuring glass, while the other is the determination of the facial angle. This is performed by drawing two lines, one from the meatus auditorius externus to the base of the nasal cavity, where it meets another drawn along the median line from the forehead to the same point; the angle included between these two straight lines is called the *facial angle.*

The variations in this angle are shown in the adjoining figures of skulls. In the highest types it is over 90°, while in the negro it falls sometimes as low as 70°, approaching to that of the monkey, in which the facial angle measures 50° in some of the higher species.

Fig. 165.

European.

Fig. 166.

Negro.

Fig. 167.

Chimpanzee.

Fig. 168.

Orang.

How are skulls measured? What is the facial angle? How does it differ in measurement in different races? What is the facial angle in the monkey?

Though a very considerable period of time is required in order to influence the configuration of the skull, we find that when the highest race is subjected for ages to debasing influences the type of the skull gradually changes, the chin becomes more prognathous, the intellect is lower, and all the energies are spent in obtaining food and in the gratification of the animal propensities.

As the life of an individual is marked by periods of development and decline, so also the lives of nations or other collections of men show the same phenomena of gradual growth in power and intellectuality until they reach a maximum, which is maintained for a certain period, after which a decline sets in, and sooner or later the nation dies of old age.

Professor J. W. Draper has divided national life into five periods, analogous to the five periods in the life of an individual. They are the Age of Credulity, the Age of Inquiry, the Age of Faith, the Age of Reason, the Age of Decrepitude; and in his work on the Intellectual Development of Europe he has demonstrated the existence of these periods, and the influence of physical agents on the course and duration of national life, in the most interesting and satisfactory manner.

What conditions change the facial angle? What is the course of life of a nation? What are the five ages of the life of a nation? Do they show the same subjection to physical agents as individuals?

THIRD DIVISION.

HYGIENE.

LECTURE XLIII.

FOOD.

Divisions of Hygiene.—Conditions essential to a healthy State of the Digestive Apparatus.—Number of Meals per Diem, and the Times at which they should be taken.—Adaptation of Food to the Age of the Individual.—Varieties of Milk.—Food of Infants.—Influence of the Diet of the Mother on the Character of her Milk.—Selection of a Nurse.—Frangipane.—Butter.—Cheese.—Age at which solid Food should be given to a Child.

HYGIENE may be studied in regard to its applications to the functions of, 1st. Digestion; 2d. Respiration; 3d. The skin; 4th. Muscular, nervous, and osseous tissues; and, 5th. Prophylactics and quarantine.

The first and most important condition to be observed in keeping the digestive organs in a healthy state is regularity in all the acts connected with them. The time at which the meals are taken should be as nearly as possible at the same hour each day. Three meals a day are sufficient for the ordinary wants of adults; the first, called breakfast, should, as its name signifies, be small in quantity, while the chief meal of the day should be taken in the afternoon, to supply the materials out of which the tissues of the body may be renovated during the night.

In his excellent work, Erasmus Wilson draws particular attention to the influence of diet. He maintains that the proper regulation of the meals is, breakfast at 8 or 9; lunch at 1 or 2, with a cup of tea or coffee; and dinner at 6 or 7. This arrangement allows an interval of five hours between each meal; and, since the stomach requires on an average three hours for the digestion of an ordinary meal, it is allowed two hours rest,

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What are the divisions of hygiene? What is the essential condition for perfect health of the digestive apparatus? How many meals a day should adults take? At what time should the meals be taken? What is the advantage of the arrangement suggested by Wilson?

which is necessary in order that it should perform its work in a satisfactory manner. The habit of eating between meals is most reprehensible, its certain result being a loss of natural appetite, dyspepsia, and a numerous train of accompanying evils. In regard to this habit Wilson says: "The stomach is a patient drudge, but tease it not, fret it not, if you would keep it in a good humor, and without its good humor, alas for yours." The great argument in favor of seven o'clock as the dinner-hour is, that nearly all men have finished their daily occupations at that time, and are ready to dismiss the "shop," together with the cares and annoyances of business, and, donning their "decent black," assume the human condition again, in which they can enjoy the pleasures of the table and fireside without the fear of some summons to business, which, by diverting the blood from the stomach to other organs, is apt to cause dyspepsia.

The above may be regarded as the most philosophical arrangement of the meals, and the majority of men follow it more or less closely, though the occupations of some, as physicians, often interfere with the rigorous adoption of any system. In the savage state there is perhaps the greatest irregularity, for the food is to be obtained by hunting, which is always uncertain in its fortune, and a savage is proverbially improvident, consequently he may often pass days without procuring a sufficient supply, and then gorge himself to repletion when opportunity offers. The result of such a system is the reduction of man to the level of a mere animal, for savages, as they are justly called, make the obtaining of food the chief object of their lives.

A proper adaptation of the food to the age and occupation is also of very great importance. Articles which agree perfectly with an adult are almost poisonous to an infant, while a continuous diet of milk would try the powers of an adult severely.

During early infancy the safest article of food is milk. If the natural supply is interfered with in any way, the proper substitute is cows' milk, diluted with two or three times its bulk of water, sweetened with sugar, and administered lukewarm. After a while, pap, formed by adding a little flour to the milk, is the most suitable article of diet until the teeth commence to appear.

Should food be eaten between meals? What is the advantage of a late dinner-hour? May all articles of food be used indiscriminately at all times? What is the best substitute for human milk in the diet of infants? How should it be prepared?

The time that a child should be allowed to nurse at the breast differs in different countries. The majority of women habitually nurse their children for two years, and even longer, to avoid the rapid succession of births, since it is exceptional for a woman to be impregnated while she is yet nursing; the menstrual flow also does not generally reappear until the secretion of milk has been greatly reduced or entirely stopped. The proportions of butter, casein, and sugar in the milk of woman, compared with that of domestic animals, is shown in the following table:

Butter.	Casein.	Sugar.
Sheep,	Goat,	Woman,
Cow,	Sheep,	Ass,
Goat,	Cow,	Mare,
Woman,	Ass,	Cow,
Ass,	Woman	Goat,
Mare.	Mare.	Sheep.

The character of the milk exerts an important influence on the health of the child, extraordinary articles of food, and medicines which have been taken by the mother or nurse, changing the secretion of the mammary gland in such a manner as to render it highly deleterious to the child. Familiar illustrations of this fact are often furnished by cows' milk, when the animal has fed on turnips, wild onions, or other vegetables that possess a marked flavor.

Special attention should be paid to the condition of the milk of the nurse or mother when children are sick, as the malady is often due to the changed state of the secretion. Advantage is frequently taken of this channel in the administration of medicines to children, and it is, as a rule, best to introduce the medicine into the system of the child by giving it to the nurse, and so impregnating the milk with the desired properties.

The choice of a nurse is a matter which parents often disregard or pass over lightly, yet it is most important as regards the future welfare of the child, for it is well known that certain specific diseases may be in this manner communicated to the child, and there is but little doubt that some hereditary diseases, as consumption, may likewise be transmitted from the nurse to the child. Some writers even consider that traits of character, such as temper, may also be communicated through this channel, but it is a statement to be received with consider-

How long should a child be allowed to nurse at the breast? How does nursing influence impregnation? What are the relative proportions of butter, casein, and sugar in the milk of woman and the domestic animals? Does the diet of the mother or animal influence the character of the milk? How may medicines be administered to young infants? What diseases may be communicated through the milk of the nurse?

able allowance; yet, as prevention is always better than cure, it is wise, in making a choice of a nurse, not only to take into consideration her own physical health, but also to pay some attention to any hereditary taint that may exist, and also to examine into her mental peculiarities. As illustrations of the prevalence of these opinions even in remote times, we may quote the Roman fable that the ferocity of Romulus was due to his having been suckled by a she wolf, while the amorousness of Jupiter was caused by his having been fed chiefly on goats' milk.

Milk, though well adapted to the wants of children, often disagrees with adults, producing severe dyspepsia. When it is desired to employ it in spite of this objection, we may take advantage of the tendency of the fluid to separate spontaneously into three constituents, viz., *cream*, *curd*, *whey*, and by administering the cream and whey, avoid the disagreeable symptoms which are nearly always produced by the curd, which coagulates in the stomach, and either passes through the intestine unchanged, or is ejected by vomiting. It is often the case that when milk is boiled it will agree perfectly; the addition of a little salt produces the same result.

An excellent preparation of milk, called *frangipane*, is formed by evaporating it to dryness, and adding pulverized almonds and sugar; it is highly nutritious, and is given with advantage to patients suffering with phthisis or consumption. Butter is of itself very digestible, but when melted it undergoes change, and is often highly indigestible. Cheese is very indigestible, and this property is increased by cooking, the Welsh rarebit being one of the most unmanageable and rebellious substances that can be introduced into the stomach. Some varieties of cheese prepared in Germany, and that made in Cheshire, in England, occasionally produce symptoms of poisoning.

The appearance of the teeth indicates the necessity of modifying the diet; more substantial articles may now be gradually added, such as well-cooked bread which is at least a day old, portions of beef and other digestible meats, and a moderate supply of fresh fruit. The quantity taken at each meal by

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What points should be attended to in the choice of a wet-nurse? When milk does not agree with an adult, which constituents may be used with impunity, and how may they be obtained? What is the effect of boiling on milk? What is frangipane? What is the effect of cooking on the digestibility of butter? What is its effect on cheese? What varieties of cheese are apt to produce symptoms of poisoning? At what time should a child commence to take solid food? What substances should be selected?

a child should be small, and the meals should be administered more frequently than to an adult, for the wants of the system at this period of life are very urgent, and four moderate meals a day will give better health than three.

In cities, the great mortality which exists among children in the summer season is chiefly due to the careless manner in which they are allowed to devour all kinds of unripe and half-decayed fruit and vegetables. Among the children of those in affluent circumstances an immense amount of evil is produced by their absurd and criminal indulgence at the tables of their parents in such articles as pork, lobster salad, new potatoes, stale fruits from the city stalls, cake, and pickles, being individually capable of giving any child a diarrhœa, and yet we often see them all administered at one meal by an indulgent parent, when the child should be in the nursery partaking of pap, with a little meat and bread, if it is desired to have it grow up into a healthy adult.

LECTURE XLIV.

OF ANIMAL FOOD.

Conditions that produce Scurvy.—Prevention of Scurvy.—Extraordinary Articles employed as Food by the Ancients and Moderns.—Peculiarities of the Flesh of young Animals.—Effect of the Food on the Flesh of an Animal.—Effect of Season.—The Fumet.—Age at which the Ox and Sheep reach Perfection.—Effect of Castration on the Flesh of Animals.—Nutritive Properties of lean and fat Meat.—Proper Time and Method of Slaughtering.—Nutritive Qualities of the Flesh of Birds.—Castration and Cramming of Birds.—Effect of Cooking on the Digestibility of Eggs.—Poisoning by unwholesome Flesh.—Fish and Reptiles used as Food.—Caviare.—The Oyster and other Shell-fish.

Though the teeth of man show that he is omnivorous, there are many tribes that live in northern regions that subsist entirely on animal food, all vegetable supplies failing in extreme northern climates. In the torrid zone, on the contrary, animal food is not employed, and it is only in the temperate parts of the earth that man can be strictly said to be omnivorous. When the system has once been accustomed to the use of a mixed diet of both animal and vegetable substances, a total abstinence from either is very apt to produce a diseased condi-

How many meals a day should be given to a child? What is the chief cause of the mortality among children during the summer season? In what region is man truly omnivorous?

tion of the system, to which the name of scurvy is given. It is a very common error to suppose that scurvy is always due to the continued absence of vegetable food, but the long-continued abstinence from animal food will produce the same result. The vast majority of cases, however, occur on ships and in armies in which there is a want of a sufficient supply of vegetable substances. The proper method for avoiding the disease is to furnish the missing ingredient, or to allow a regular ration of lemons or some vegetable acid, such as vinegar. The modern system of preserving vegetables by hermetically sealing them has obviated all necessity for the existence of this disease, and it will doubtless, in future, be almost unknown in navies, when it is so much to the interest of governments to preserve the health and efficiency of their sailors.

All parts of animals, excepting some of the secretions, are or have been employed as food. Among the ancient Romans, the brains of the ostrich and peacock, and tongues of nightingales and other singing-birds, were much sought after. The vulva of the sow was also highly valued as a dish; and the gravid uterus and fœtal pigs of one of these animals that had been trampled to death was considered worthy of the table of an emperor. They were also very fond of the flesh of the young ass; and young fat puppies were a great dainty in Corsica, and continue to be held in high repute among the Chinese. At the present time the Tartars esteem the after-birth or placenta as a great delicacy, and the civilized disciple of Epicurus in our own country regards the trail of the woodcock as the *bonne bouche* of his most luxurious dinner.

Among the extraordinary substances employed as food we may cite the instance of the quarrymen of Thuringia, who eat a substance called *rock-butter*, which they spread on their bread. A species of clay is an article of diet among the Ottomaques of South America, and Humboldt states that they devour enormous quantities, so that their stomachs are greatly distended; he also thinks that they derive some nutriment from it. This is not at all improbable, for the clay that is eaten by the troglodites of South Carolina is found to be composed, to a considerable extent, of animalcules. The amount of nutriment that may exist in substances which are apparently devoid of it is well shown by the growth of gold-fish, which are kept for

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What are the conditions that produce scurvy? How may scurvy be prevented? Mention some of the articles regarded as luxuries by the Romans. Mention some of the extraordinary substances at present employed.

years in a small globe of water, and, though they are never fed, obtain sufficient food from the animalcules in the water, and animal and vegetable ova falling into it from the circumambient air, to reach a very considerable size.

The flesh of young animals contains a greater proportion of gelatin than that of the adult; it is therefore softer and more soluble in water, though not more digestible, as is shown in the instances of veal and lamb, both of which are less digestible than beef and mutton.

The effect of food on the flesh of animals is shown by the rank character of that of the carnivora. The nations that eat the flesh of such animals generally cause them to subsist on a vegetable diet, so as to render their flesh edible. The great superiority of the Virginia hams over those made from still-fed hogs is in great measure due to the fact that the former are allowed to roam through the forest, and subsist on acorns, chestnuts, and roots, and are finally fattened on corn, and not on swill or household garbage.

Many animals are unfit for use as food at certain seasons. Pork, for example, is not used during the summer, and the flesh of the buck is valueless in the rutting period. The flesh of most animals reaches perfection in the early part of the winter, at which time our tables are so freely supplied with game, which is then in season. The flesh of the females that have been recently delivered is not fit for use, being tasteless and insipid, and not regaining its flavor until some time after the lapse of the suckling period.

The digestibility of all meats is improved by keeping them until they commence to give evidence of incipient decomposition. Meats are generally cooked too soon after the animal is killed, and with us venison and game are the only articles of food that are allowed to gain their true flavor. In Great Britain mutton is always hung until its flavor is *pronounced;* and the game served at the table of an epicure usually gives unequivocal evidence of having been kept for some time, since it requires educated olfactory nerves to withstand the perfume evolved, to which the euphonious designation of the *fumet* has been given. It is said that the Siamese carry this system to the greatest perfection, and consider the decayed egg that contains a chick the special delicacy with which to tempt a guest.

What is the peculiarity of the flesh of young animals? Is the flesh of young animals as digestible as that of those that are full grown? Does the food of an animal have any effect on its flesh? How does the season influence the flesh of animals? What is the effect of keeping meat on its digestibility? What is the fumet?

In the United States there is not sufficient attention paid to the age of the slaughtered animals, our butchers killing their stock when it is demanded, or when they can obtain it, without any reference to its size, condition, or age. In the London markets the ox is regarded as reaching perfection at about the seventh year, and the wether-mutton of England, which has earned a world-wide reputation, is not killed till the fifth year. The effect of castration on the texture and flavor of meats is very singular, that of the neutral or castrated animal being far superior to that of either the entire male or female; the fat also is more evenly distributed, and the meat has a higher nutritious power, since it is said that one ounce of fat meat will furnish an amount of nutriment equal to that obtained from four ounces of lean meat.

Before being slaughtered, animals should be kept without food; for, if the gastric juice is being secreted rapidly at the time of death, it is apt to perforate the stomach, and induce changes in the flavor of the flesh. These effects are more frequently found in fowls than any other article offered for sale in our markets, the object being to increase the weight of the bird. All poultry with a distended crop or craw should therefore be avoided, for the flesh is very apt to possess a disagreeable flavor.

It was the custom at one time to bleed animals to death slowly, and killing animals by the chase is still thought to improve the quality of game. In some of the receipts in the cookery books of past times we find such directions as the following: "*To make a pig taste like a wild boar.*—Boil together in vinegar and water some rosemary, thyme, sweet basil, bay leaves, and sage; then take a living pig, make him swallow the above drink, and whip him to death, and roast him immediately." It is supposed by many that the vinegar in the preceding preparation softened the muscular tissues, and rendered it more digestible. It is said that the proper way to kill a hedgehog is for two men to take him by the legs, and rub his back backward and forward over some hard substance like a stone until it ceases to squeal, and then cut his throat.

The method of slaughtering now adopted in civilized countries is either to cut the throat, or, in the large animals, to

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At what year does the ox reach perfection? At what age should mutton be killed? What is the effect of castration on the flesh of animals? What is the relative nutritive power of lean and fat meat? What is the objection to slaughtering animals immediately after eating? What is thought to be the effect of administering vinegar to an animal about to be slaughtered? What is the method of slaughtering adopted in civilized countries?

knock them on the head, and then cut their throats as quickly as possible, that the blood may flow out of the body. In the French abattoirs they then beat the slaughtered animal with staves, and inject air into the cellular tissue by means of a suitable forcing apparatus, which operation greatly improves the appearance of the meat.

The flesh of birds whose meat is dark is much more nutritious than that of the white-fleshed birds; and Stark states that in the series of experiments he undertook on diet, he found that he was more vigorous when he ate roast goose than any other article, but that may have been in part due to the brandy which he probably took as a "peptic persuader," as it has been quaintly termed.

Castration has the same effect on birds as on animals, rendering their flesh more palatable and delicate, a crammed *capon* or *poulard* being one of the most highly-esteemed of modern dishes. It is said that the Romans blinded the fowls that were to be crammed, to insure their being in the dark. The method of cramming at present employed is to keep the fowl in a dark warm place, and force down their throats every hour a paste made of barley meal, molasses, suet, and milk. In a couple of weeks the operation is finished, but if continued longer the creature is liable to an attack of fever, and is then unfit for use.

The digestibility of eggs depends on the manner in which they are cooked, frying being the worst method, as is shown by the table page 59. The French writers on cookery mention more than 600 preparations of eggs, but of these the most digestible is that in which they are boiled soft, in which state they are slightly laxative, while by all the other methods they are rendered more or less constipating.

The flesh of animals that have died from natural causes is universally known to be unhealthy, and numerous instances of death from the use of such food are recorded. As an illustration, we furnish a case from the London *Medical Repository*, which states that in 1826 a family on the Galloway coast ate a stew made of the meat of a dead calf. They all suffered with violent pain, purging, vomiting, and, when aroused from the stupor into which they quickly fell, the countenance assumed a wild expression; one died in about six hours, but the rest

What class of birds furnish the most nutritious flesh? What is the effect of castration on the flesh of birds? What is meant by cramming, and how is it conducted? How does the method of cooking influence the digestibility of eggs? Is the flesh of animals that have died from disease fit for use? What are the symptoms produced by eating unwholesome flesh?

eventually recovered. The stew had a nauseous smell and a black color. In his work on Poisons, Dr. Christison cites a case of a family that partook of broth made from beef which had a black color, and which caused symptoms similar to those described above, and which he thinks were due to the unsound state of the meat.

The articles which are more apt than any others to produce the symptoms related above are the sausages made of liver, meat, and blood, and which are very generally used by Germans. The poison they contain is very dangerous, and it is said that in the Würtemberg territories 234 cases of poisoning from this cause were recorded between 1793 and 1827, of which 110 were fatal.

Bacon, and all cured meats, together with cheese and milk, have from time to time furnished undoubted cases of poisoning when they have undergone change.

Salted meats are more indigestible than those which are fresh, and when dried and salted they are only dissolved with great difficulty by the gastric juice.

The class of reptiles furnishes but few representatives to the table, but these are highly prized; we need only mention the turtle and frog, and all epicures will at once acquiesce in the statement. In addition to these, the eggs of many reptiles are also used, and some of the Asiatics eat the flesh of certain varieties of lizards.

Fish forms the principal article of diet of many nations, but they are generally a poor and miserable class of people, devoid of all ambition, and steeped in poverty and ignorance. St. Jerome gravely relates the story that when the executioner attempted, by the order of Nero, to bleed Seneca to death, he could not find any blood in his veins, because he had lived on fish and fruit.

It is a very common idea that a fish diet renders a population very prolific, and the great proportion of children found in China gives support to the opinion. It has also been stated that a fish diet is liable to produce leprosy; at all events, it is a well-known fact that a continuous diet of fish is conducive to the production of nearly all skin diseases, and there are many persons who suffer severely with herpes, and other painful skin diseases, if they eat the smallest portion of fish, and especially

What sausages produce similar symptoms? What other articles of food cause poisoning? Are salted meats as digestible as those that are fresh? What reptiles are used as food? What is the effect of a long-continued fish diet? What variety of fish is most apt to produce herpes?

of shell-fish. All fish that have commenced to assume the putrefactive state are unsuitable for use as food, and should never be eaten. We may also say that all fish lose by being kept, and if it is desired to serve them in full perfection, they should be cooked while yet animate.

Among the substances that are highly prized by epicures is a preparation of the roe of the sterlet or sturgeon, which is known as *caviare*. The best is obtained from Russia; that derived from the American sturgeon is very indigestible, and produces severe gastric disturbance. At the head of the list of edible fishes we place the trout and salmon, which are universally esteemed, and yet it is said that even these may be improved by castration.

Of shell-fish the oyster is the most digestible, especially when eaten raw, and with the addition of a little Cayenne; they are well adapted in this form to invalids who are just commencing to convalesce. Those that are transplanted are edible at all seasons, and possess a good flavor during the spawning season, *i. e.*, May, June, and July, when the native oysters are not edible. Oysters are generally thought to possess an aphrodisiac power, but the statement is not founded on facts.

In Switzerland the snail is much esteemed, and gardens are devoted to their cultivation. Crabs and lobsters are held in high repute in all cities on the sea-shore, and the clam and mussel also have their admirers, but the latter are more liable than any other fish to produce symptoms of poisoning.

The effects of the various methods of cooking have been shown in the table (page 59), in which it is demonstrated that the method by broiling is the best. In boiling, a considerable portion of the nutritive material is removed by the solvent action of the water, so that we can prepare in this way extracts of greater or less strength, which are generally known as soups. If the meat is placed in the water when it is cold, and the temperature of the liquid gradually elevated, the loss of nutritive material will be far greater than when the flesh is dropped into boiling water. In roasting, the crust that forms on the exterior of the joint prevents the escape of the nutritive portions; and though the mass may lose more weight than if it was boiled, owing to the evaporation of water and melting of fat, it possesses greater nutritive power. It is said that beef loses

Is stale fish fit for use? What is caviare? What is the effect of castration on the flesh of fishes? Under what form is the oyster most digestible? How may it be rendered edible at all seasons? What other shell-fish are used as food? What is the best method of cooking? How should soups be prepared?

by boiling one fourth of its original weight, and mutton one fifth, whereas they both lose about one third by roasting.

LECTURE XLV.

OF VEGETABLE FOOD.

Vegetable Food less wholesome than Animal Food.—Bread best adapted to Dyspeptics.—Indigestible Character of Pastry.—Rusted or Ergot Rye. — Prejudices against the Use of Oatmeal. — Use of Cornmeal. — Pellagra.—Polenta.—Use of Legumens.—Indigestibility of Nuts.—Effect of Cooking on Digestibility of Potatoes.—Use of raw and cooked Cabbage. —Salads.—Sugar does not injure the Teeth.—Concentrated Solutions of Sugar most Digestible.—Classification of Condiments, and Effect of insufficient Supply of Salt.—Anchovy and Bloater Pastes.—Use and Abuse of Vinegar.—The aromatic Condiments.—Effect of Climate on the Nature of Diet.—Effect of Occupation on Diet.—Idiosyncrasies.—Effect of Irregularity in the Evacuation of Fæces.

Far greater care is requisite in the selection of vegetable than of animal food, for there are many plants which possess an injurious action on the human system, and many of those which are in ordinary use frequently become so changed in their character as to cause violent disturbance to the digestive apparatus, which is sometimes so severe as to result in death.

The chief article of food of a vegetable origin is bread, and we have (in Lecture XI.) mentioned some of the varieties employed and the mode of preparation. When bread made from the finest wheaten flour produces dyspepsia, it will be generally found that the flour which contains a portion of the bran will furnish bread that will be digested with ease, the bran acting as a gentle stimulant to the stomach and intestines.

The preparations of wheaten flour known as *vermicelli* and *macaroni* are very nutritious and easily assimilated; but all articles of pastry are unwholesome, and cause dyspepsia more frequently than any other substances. The lighter varieties of puddings are wholesome, but those made with fat or suet are very indigestible, as the fats are not acted on in the stomach, and, by covering the particles of flour, protect them from the action of the gastric juice.

Rye is also extensively used in the preparation of bread, and

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What is the relative loss of weight of beef and mutton by roasting and boiling? Are vegetables as uniformly wholesome as animal food? What variety of bread is best adapted for use by dyspeptics? Is pastry digestible? Why are articles prepared with fat or suet indigestible?

is an excellent article of diet. It is, however, liable to a disease called the rust, which also passes under the designation of spurred rye, or ergot; such grain produces violent contractions of the uterus, and when used for any length of time as an ordinary article of diet, causes dry mortification of the extremities.

Though it is highly nutritious, there is a common prejudice against the use of oatmeal, many people thinking that it is apt to produce cutaneous affections, and that it is one cause of the existence of such diseases in Scotland; but the same diet is employed in the north of England, and skin diseases do not exist there to any very great extent, showing that there must be some other cause than an oatmeal diet for their prevailing so extensively in Scotland.

Rice flour and potatoes are often added to wheat flour in the preparation of bread; there is no objection to their use, and in skillful hands they are a decided improvement. Indian corn is in common use in this country, and in the Southern States has always been the chief article of diet for the slaves. It is not well adapted to the constitutions of those who are liable to intestinal disturbances, and who are not accustomed to it. Many will be surprised to learn that in Lombardy a loathsome disease, called *pellagra*, has appeared during the last century, which has been attributed to the introduction of Indian corn as an article of diet, the Italians being very fond of a dish called polenta, which is composed of cornmeal and cheese.

The legumens, as peas and beans, are highly nutritious, and form, when dried and thoroughly cooked, an excellent article of diet for those who are obliged to work hard. Some varieties are eaten with the pod when they are very young and tender, but they are very indigestible unless they are well boiled. The nuts that are introduced at many tables are all more or less unwholesome, since they contain oils which are not acted on in the stomach, and consequently the digestion of the farinaceous parts is thrown on the lower intestine, and is imperfectly performed.

Of the roots, the beet, carrot, parsnip, turnip, etc., all contain sugar, and are slightly nutritive when young. They should be well dried before they are eaten. The radish, onion, leek, and such articles, are all indigestible, and should be employed in small quantity as condiments rather than as articles of food.

Under what circumstances is rye unfit for use? What prejudice exists against the use of oatmeal? Is there any objection to the addition of rice flour or potatoes to bread? Under what circumstances does cornmeal disagree? What is pellagra? What is polenta? What are legumens? Are they adapted to all constitutions? Why are nuts indigestible?

Of the varieties of potato, those which are mealy are the most digestible, but it depends to a great extent on the manner in which they are cooked. If they are sodden in salt water, the best potatoes will be injured; the proper methods to be employed in preparing them is either by steaming or roasting until they almost fall to pieces. The potato is at times liable to be destroyed by a disease which commences in the interior, and which is commonly known as "the rot." It has occasionally produced great suffering among such nations as the Irish, who make it the chief article of food. The sweet or Carolina potato is very nutritious, but is not so easy of digestion as the Irish or common potato.

The vegetables of which the cabbage, asparagus, spinach, and cauliflower are examples, often disagree with those who are not dyspeptics, and the great majority of people find that cabbage is much more digestible when eaten raw than when it is cooked. Lettuce, celery, and the like salad herbs are almost invariably employed in the uncooked state, and often agree with a dyspeptic when mingled with oil, mustard, vinegar, and condiments, while in the undressed state they would cause a severe attack of indigestion.

Mushrooms, cucumbers, and tomatoes are all held in high esteem as delicacies, yet they belong to classes of which some of the members are very poisonous. This is especially the case with the mushroom and cucumber.

The fruits are all wholesome in their proper season, when they are fully ripe, and have not been kept for too great a period of time. Some, as the varieties of melon, produce diarrhœa in certain people, and are often suspected as being the cause of visitations of cholera. The evil consequences which arise from the use of these and other fruits may be to a great extent avoided by carefully rejecting the skins, core, and seeds, and using the pulp only.

All fruits contain sugar, which is very commonly supposed to injure the teeth, but this is a mere prejudice, which has probably arisen on account of economic reasons, for it has no true foundation in fact, since the negroes of the South in the sugar season partake of the juice of the sugar-cane very freely,

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What varieties of potato are most digestible? How does cooking affect the digestibility of potatoes? What is potato rot? Is the Carolina potato as digestible as the common potato? In what form is cabbage most digestible? Under what form are the salad herbs most digestible? How may the evil consequences of eating fruit be in a great measure avoided? Why are we justified in supposing that the free use of sugar does not injure the teeth?

and grow fat on it, yet their teeth are not injured, but are universally known and admired for their beauty of form and whiteness. It is estimated that in France the annual consumption is 5 lbs. per capita; in the United States, 10 lbs.; and in England, 14 lbs. Concentrated solutions of sugar often digest readily, when a dilute sirup, in which the amount of water is very great, is highly indigestible. It is owing to this cause that tea and coffee so often disagree.

Condiments are substances employed to assist digestion; they generally contain either a bitter aromatic or an oily acrid principle. Another class, of which salt is an example, are purely saline, and we may justly regard it as the most important of all the condiments, since it is absolutely necessary to the proper performance of digestion; and when it is not used in proper quantity both by men and animals, we find that there is a disposition to the formation of parasites in the digestive canal; for in those countries in which the criminals are forced to subsist on a diet from which salt is excluded, the unfortunates are literally destroyed by the worms that are produced in the digestive canal. In ancient times, salt was the first thing placed on the table and the last removed; and it is still the custom among the Dutch families, when they change their residence, to take to their new abode first of all things a Bible, for God's blessing; *a bag of salt*, as the emblem of hospitality; a loaf of bread, as the symbol of plenty; and a broom, to typify cleanliness.

The anchovy, bloater, and other paste-like condiments, which are prepared from salted fish, are very indigestible, and should only be employed in small quantity.

Vinegar alone, and in the form of pickles, is a useful condiment, and we have already alluded to the property it possesses of assisting the gastric juice. There is a common idea that when freely used it reduces *embonpoint*, and aids in producing a slender, spider-like waist. Whatever effect it may have on the figure is of very small importance compared with the fact that, when used in such excess, it is utterly destructive of the digestive powers, and, by the indigestion produced, causes not only the waist, but all the other tissues to shrivel up, and reduces the sufferer to mere skin and bone. The action of lemons, and other acid fruits and juices, is similar to that of vinegar.

Are concentrated or dilute solutions of sugar most digestible? Why do tea and coffee so often disagree? To what classes of substances do condiments belong? To what class of condiments does salt belong? What is the effect of an inadequate supply of salt? Are the anchovy and such pastes digestible? What is the effect of the abuse of vinegar?

The aromatic condiments or spices, as ginger, cloves, nutmeg, cinnamon, pepper, mustard, horseradish, onions, etc., are extensively employed in all parts of the globe, since they assist the deficient digestive powers of those whose stomachs are torpid, and aid in the digestion of articles of food which would otherwise cause indigestion. They act by stimulating the glands of the mouth and stomach, and causing them to secrete their fluids with greater rapidity.

Variation in climate should be met by variation in the nature of the food. An Englishman may drink with impunity beer and alcoholic fluids in his native land, but if he continues the habit under the hot sun of India his liver is quickly diseased, and his life shortened or forfeited. The inhabitants of hot climates require but little respiratory food; they are consequently freely supplied by Nature with a great variety of sweet fruits, the sugar of which furnishes all the combustible material they need, but in cold climates a large quantity of calorifacient food is required to sustain the animal temperature. The inhabitants of such regions therefore resort to the use of fats and oils, without which they could not exist.

Occupation also exercises a great influence on digestion. A soldier will consume his allowance of fat pork and beans every day while he lives in the open air and has to undergo a severe drill. A laborer will also enjoy the same food with appetite; but if a student or person of sedentary habits partakes of it many times in succession, he will suffer severely from indigestion so long as he continues his inactive life; but when he leaves his desk, and, taking his rod or rifle, lives in the open air, he will enjoy a daily allowance of gross oleaginous food with as much relish as a soldier.

After paying proper attention to the influence of the method of cooking and the occupation of the individual on the digestibility of food, there still remain certain personal peculiarities or idiosyncrasies, as they are called, which each person must notice and study for himself. Some will suffer torture from eruptions on the skin if they eat ever so small a portion of shell-fish. The odor of a rose or of new hay will produce asthma in another, while they afford pleasure to the majority of people. When, therefore, an individual finds that any article of diet produces trouble in his digestive system, he must exert his own good sense in the matter and avoid it.

How do the aromatic condiments act? Does variation in climate affect the power of digesting food? What is the effect of occupation on the digestive function? What is meant by idiosyncrasies?

Not only should regularity be observed in taking the meals, but the evacuation of the fæces from the intestines should take place every day at the same hour. By attending to this duty with regularity, a person will enjoy far better health, and avoid those disagreeable and annoying headaches which are certain to arise when constipation exists. Medicines may be used to afford relief for a time, but it is the tendency of most purgative drugs to produce a constipating effect after the purgative action; they should be therefore avoided, and the habit of evacuating the intestine at a certain hour established, when trouble will very rarely arise.

Habit is the most powerful of all agents in its effect, not only on the digestive, but also on the other systems of the body. It should therefore be cultivated to as great an extent as possible, for the body quickly accommodates itself to any given duty, and accomplishes a definite amount of work with far greater ease when it is accustomed to it.

LECTURE XLVI.

FLUIDS USED AS DRINK.

Causes that produce Thirst.—Temperature at which Water should be employed as Drink.—Use of Ice.—Natural Waters.—Differences between Rain and Spring Water.—Effects of Lime-water on the System.—Effect of Salines on rapidity of Absorption of Water.—Goître.—Materials suitable for making Water-pipes and Tanks.—Protection of Lead Pipes.—Precautions to be employed in the Use of Lead Pipes.—Purification of Water by Filtration and Distillation.—Objections to the Use of sweet Drinks.—Toast-water.—Gruel.—Properties of Tea and Coffee.—Introduction of Tea.—Classification and Composition of Tea.—Effects of the Abuse of Tea.—Introduction of Coffee.—Preparation for Use.—Chocolate.—Soda-water.

As hunger is the evidence of the demand of the system for solid aliment, so thirst shows the desire of the body for fluid wherewith to dilute its circulating juice, and furnish the liquid required for the urine and perspiration. The experiments of Dupuytren demonstrate that the sensation of thirst may be allayed by injecting water into the blood-vessels; it would therefore seem to be dependent on the amount of water contained in the circulating juice.

Water is the natural drink of men and animals, and the ma-

What is the effect of regularity in evacuating the fæces? Upon what condition of the system does thirst depend?

jority of nations use it at the temperature it possesses when issuing from the earth. Some valetudinarians insist that it should always be taken at a temperature of 90° or 100°. But it appears far more natural to employ it at lower degrees, such as 40° to 60°, which is the ordinary temperature of spring or well water. The use of ice-water is objected to by many; but when we reflect that its temperature can not be lower than 32°, and that of natural water is from 40° to 60°, the objection appears to be trivial, and not worthy of consideration.

Rain is the purest form of water furnished by Nature. The first portions which fall in any storm wash the air, and remove the floating dust and noxious gases which it contains; this is admirably adapted to the wants of plants, but not so well suited to animals, though it is purer than the water usually employed. The rain which falls during the latter part of a long-continued storm is absolutely pure, and may be used for the same purposes as distilled water.

Spring and well water always contain a certain proportion of solid inorganic materials, derived from the strata through which the fluid has percolated. In lime districts the quantity of carbonate of lime in the water is very large, and produces diarrhœa when used by persons unaccustomed to it. The evil results of the use of such waters may be in part avoided by boiling them, which expels the carbonic acid gas in the liquid, and causes the lime to be precipitated.

It often happens, especially in large cities, that in passing through the soil the water dissolves enormous quantities of organic matter from some sewer or other receptacle of filth. Such water is often remarkably pellucid and pure in appearance, but in its action on the system it is most deadly, producing the worst forms of dysentery and low fevers. The impurities may be detected by an ordinary chemical analysis.

Water, of all liquids, allays thirst with the greatest rapidity, and is absorbed with the greatest ease by the veins of the stomach. The presence of a very small proportion of saline material in water reduces the rate of absorption, an individual being able to drink a far larger amount of rain or distilled water than of that obtained from a spring or well. When dis-

At what temperature is water generally employed? Is there any objection to the moderate use of ice? What is the purest form of natural water? Are the first portions of rain that fall as well suited to the wants of animals as of plants? What is the difference between spring or well water and rain-water? What is the effect of lime-water on the system? How may the lime be removed? What are the peculiarities of water containing organic matter? How does the presence of saline matter in water influence its rate of absorption by the veins of the stomach?

tilled water has been taken in these large quantities, it passes off almost immediately by the kidneys, the urine gradually containing less and less solid material. It has been humorously proposed that in diseases we should, by drinking enormous quantities of distilled water, wash out the system just as we cleanse a soiled garment.

It was formerly supposed that the water obtained from melted ice or snow produced the disease known as goître, which is a swelling of the glands of the throat; but as it exists also at the base of mountains on which snow never falls, it is evident that it is due to some other cause. The elephantiasis, which prevails in Egypt, was also supposed to be produced by the use of the waters of the Nile; but it is almost impossible to fix on water as the true cause of these and other diseases which are endemic in their nature, since they may also be produced by peculiarities in the air or vegetable growths of such regions.

When the water from lakes and rivers is placed on ships, it undergoes fermentation in the tanks, and deposits a large amount of sediment. After this purification, though it may retain the odor and flavor of some of the products of the action, it is much more wholesome and less liable to produce diarrhœa and other intestinal troubles.

The best materials that can be employed in the manufacture of the tubes for conveying and tanks for holding water are glass, wood, and iron, since they do not impart any poisonous qualities to it. Lead and copper are used, but there are great objections to them, since if water is allowed to remain in vessels made of these metals it soon acts on them, and becomes more or less impregnated with metallic salts, which render it highly deleterious. In the case of lead, which is so generally used in cities, the purer the water, the more liable is it to act on the metal; but when it contains sulphates in solution, the sulphuric acid, having a great affinity for the lead, unites with its oxide, and forms on the interior of the pipe a thin insoluble coating of sulphate of lead, which protects the pipe from farther action; consequently, the water drawn from old pipes is usually free from lead, while that taken from a pipe that has just been laid is generally more or less contaminated. Even in the case of old pipes it is best to reject the first portions of wa-

What is goître, and what was supposed to be its cause? What change occurs in the river-water placed in the tanks of ships? What are the best materials that can be employed in the manufacture of water-pipes and tanks? What variety of water acts with the greatest energy on lead pipes? How do waters containing saline matter protect the lead from corrosion? What precautions should be taken in using water from lead pipes?

ter that are drawn in the morning, and which have rested in the pipes during the night, since they frequently contain an appreciable amount of lead, even though the pipe is coated in the interior with a layer of sulphate.

Many of the impurities contained in water may be separated by filtration. On the great scale, this may be done by passing it through many alternate layers of charcoal and sand, which should be from time to time renewed. In Paris there is an establishment at the *Quai des Celestins*, where an immense amount of water is purified by first passing it through sponges, then through filters such as those described above, and finally causing it to fall through air in a fine rain, to allow it to absorb the gases it has lost during the purification.

On steamers, a liberal supply of water can be obtained by the condensation of steam. The only objection to distilled water is its insipid taste; but this can easily be avoided by agitating it with air, or allowing it to fall through a column of air, as in the Parisian establishment spoken of in the preceding paragraph.

The infusions of various animal and vegetable substances are extensively employed by all nations as drinks; some of these, as lemonade, are acid, while others are sweet, as the *eau sucrée*, and the various sirups prepared with fruits and sugar. Though such fluids are often gratifying to the palate, they are, as a rule, injurious, and produce indigestion, attended by heartburn and flatulence.

Toast-water, made by immersing well-toasted bread in cold water, is to many a very grateful drink, and rarely does harm. It often relieves the breath of the disagreeable odor that it possesses in some people.

Gruel made from coarse oatmeal is an excellent article either for breakfast or supper when the powers of the stomach have been enfeebled by indulgence. It is also extensively employed in the diet of parturient women, being very nutritious, and tending to relieve the constipation which usually attends the period of gestation.

Tea and coffee form prominent constituents in the daily diet of the majority of the inhabitants of the globe. They are possessed of considerable power as nervous stimulants, and are pleasant beverages. It has been satisfactorily demonstrated

How may impurities be removed from water? How may the insipid taste of distilled water be removed? What are the objections to the use of sweet drinks? What is toast-water, and what are its properties? Under what conditions of the system does oatmeal gruel afford relief? What are the general properties of tea and coffee?

that they not only act as direct stimulants when taken after the performance of fatiguing work, but also prevent the waste of tissues during labor, and are therefore of value from an economic point of view.

Tea was first imported into Europe by the Dutch in 1664, and is now extensively employed as a drink by many nations in the form of an infusion of the leaf. There are many varieties of tea, but they may all be reduced to two orders, viz., green and black. The varieties of the first class in common use are the *hysons*, *imperial*, and *gunpowder;* of the second, the *souchong*, *oolong*, *pekoe*, *pouchong*, *bohea*, *campo*, etc. An analysis of tea shows that it is composed of extractive, resin, tannin, gallic acid, and mucilage, the greatest proportion of the astringent principles being found in the green teas. When taken in too strong an infusion it produces restlessness and wakefulness, owing to its stimulating properties.

Coffee was first publicly sold in England in 1652. The best is that from Mocha, on the Red Sea; next in value is the Java; while those from Brazil are the poorest. The value of coffee depends in a great measure on the care with which it is roasted: if the heat has been deficient in intensity, or has not been continued long enough, it is bitter; if it is applied for too long a period, all the aroma is expelled, and it is tasteless. It is best to grind and use it as soon as it is roasted, and when ground it may be kept in closely-stopped bottles for a considerable period without deteriorating. It is better to prepare it as an infusion than as a decoction, for in the latter method the long-continued application of heat expels the aromatic principle.

Coffee is both tonic and exhilarant, and is held in high esteem by the student; it is regarded as an intellectual stimulant, and has been the brain-fuel of many distinguished authors and litterateurs. When freshly made, and taken in small quantity after a meal, it assists digestion; but it should not be used in excess, or mingled with sugar or milk, as it is then apt to produce indigestion.

Chocolate is the pulp of the cacao or chocolate nut, which is roasted, ground to a powder, and flavored with vanilla, cinnamon, or other aromatics. When prepared as a drink it is very

When and by whom was tea introduced into Europe? What are the two classes of tea? What are the constituents of tea? Which class of tea contains the largest proportion of astringent principles? What is the effect of the use of an excess of tea? When was coffee introduced? What is the finest variety of coffee? How is the berry prepared for use, and what precautions should be taken in its preparation? How may its aroma be retained? What are the properties of coffee? How should it be used after a meal? What is chocolate?

indigestible, and should be avoided by all who have a tendency to dyspepsia.

The soda-water made by condensing and dissolving carbonic acid gas in water is a pleasant and agreeable drink, and acts as a gentle stimulant to the gastric mucous membrane. When the powers of the stomach are reduced by the excessive use of stimulants, or when there is prostration from over-excitement, a little brandy mingled with the soda-water described above is one of the best restoratives that can be employed, the carbonic acid of the soda-water seeming to hasten the absorption of the alcohol, as is shown by the rapidity with which the brisk wines, as Champagne, produce an intoxicating effect.

LECTURE XLVII.

ALCOHOLIC STIMULANTS AND TOBACCO.

Classification of fermented Liquors.—Times at which alcoholic Fluids should be taken.—Effects of the Abuse of alcoholic Drinks.—Preparations of Wines.—Must.—Imperfection of our Grapes.—Composition of Wine.—Its Bouquet.—Effect of Age.—Causes that Influence its intoxicating Power.—Port.—Sacks.—Sweet Wines.—Malt Liquors.—Liqueurs.—Liquors: Brandy, Whisky, Gin, Rum.

Tobacco, its Introduction.—Forms in which it is used.—Effects on the olfactory Nerve.—Principles in Tobacco.—Effects of excessive Smoking.—Training.

In the class of fermented liquors we include all varieties of wine, ale, and other malt liquors, and the strong spirits, as brandy, whisky, etc.

Alcoholic fluids are of two classes—those which contain a small percentage of alcohol, such as beer, ale, and the light wines, and those which contain a great percentage, as brandy and whisky. The first are employed to such an enormous extent by certain nations as to have become national in their character, the English and Germans resorting to the use of the different varieties of beer, the French and South Europeans employing claret and light wines, and the North Europeans the strongest alcoholic liquors.

Alcoholic fluids, when used in moderation, belong to the class of respiratory food. If taken before exercise or labor

Is it digestible? What is soda-water? How does it act when mingled with stimulants? Give examples of fermented liquors. What are the two classes of alcoholic liquors? What nations employ the first class of liquors? What nations are habituated to the use of the strong liquors? To what class of food do the alcoholic fluids belong?

they may be injurious, since they stimulate the individual to undertake a greater amount of exertion than his system can bear. The proper time to take stimulants without injury is after the labor or work is finished, when they aid in restoring the system to its perfect state.

The excessive use, or rather abuse of alcoholic fluids, is, of course, not to be for a moment tolerated. It not only for the time converts the man into a beast, but steadily undermines the constitution, utterly destroying the tissue of the kidneys and other organs, and producing such changes in the substance of the brain as to cause incapacity and mania.

Wines are prepared from the juice of the grape, which is called *must*. This is caused to ferment at a certain temperature, by which alcohol and carbonic acid are produced, the proportion of alcohol obtained depending on the amount of sugar in the must. In the juice of our domestic grapes the sugar is deficient in quantity, and it is necessary to add a sufficient amount to exhaust the ferment in order to make a good wine.

When analyzed, wines furnish the same constituents; in addition to alcohol, there is water, mucilage, tannin, coloring matter, various salts, and acetic acid. The flavor of the wine is called the *bouquet*, and is probably due to an oily compound, which in some varieties exists in the fruits, and in others is the product of the vinous fermentation. Many wines, as sherry, are flavored by the addition of almonds. The stimulating properties depend in a great measure on the amount of alcohol contained, as is shown by the following table from BRANDE:

Marsala	25·1	Malmsey Madeira	16·40	Tokay	10·
Port	23·5	Scheraaz	15·5	Elder Wine	10·
Madeira	24·2	Syracuse	15·2	Rhenish	9·
" average	22·2	Sauterne	14·4	Cider	5· to 10·
Sherry, average	19·2	Burgundy	14·5	Perry	7·
Lachryma Christi	19·7	Hock, average	8·9	Mead	7·
Malaga	18·9	Rudesheimer, average	11·5	Ale	5· to 9·
Cape Muscat	18·2	Johannisberger	8·7	Brown Stout	7·
Cape Madeira, average	20·5	Barsac	13·8	Porter	5·
Calcavella	18·1	Champagne	12·5	Small Beer	1·2
White Hermitage	17·5	Red Hermitage	12·3	Brandy	53·
Roussillon	18·2	Frontignac	12·8	Rum	53·
Claret	12· to 17·5	Gooseberry Wine	12·0	Scotch Whisky	54·
		Orange Wine	11·2	Irish Whisky	54·

Age impresses great changes on wines, which render them

At what time should stimulants be taken when they are needed by the system? What is the effect of the abuse of alcoholic stimulants? How are wines prepared? What is the name given to the unfermented grape-juice? What governs the amount of alcohol in the wine? What addition is necessary in the case of the grapes of the United States? What are the constituents of wine? What is the *bouquet?* Upon what ingredient do the stimulating properties of the wine depend?

more valuable, and less liable to produce hepatic and renal troubles. The tartar, and a part of the coloring matter, are deposited in the form of a crust, and the alcohol either is united with, or is converted into the oily material, so that the *bouquet* is improved and the wine is less intoxicating.

Burgundy wines are far more heady than clarets, though the proportion of alcohol is generally less; this is apparently due to the peculiar character of their bouquet, which is very powerful. Of all the wines, claret is best adapted for ordinary daily use, since it contains but little alcohol, and its astringent bitter principles often aid a feeble digestive apparatus.

Port is chiefly used in Great Britain, and is especially prepared by the addition of a large amount of brandy, to increase the strength; tannin is also added, to give the desired astringency, rendering it almost impossible to find a pure article in any part of the world, since these impurities are added at the vineyards to adapt it to the English market.

The sacks, or dry wines, in which all the sugar is converted into alcohol, and of which sherry is the most common example, are in very general use, and are much less apt to cause gout than port. Many persons who can not drink sherry without an attack of indigestion can use Madeira with impunity.

The *sweet wines*, as Tokay and Malmsey, differ from the sacks in that they contain a large quantity of sugar that has not undergone fermentation. They are not well adapted to the stomachs of dyspeptics, and should only be used as cordials.

Cider, perry, ale, and other malt liquors, are very extensively employed, being in some countries national in their character; and although the ultra fastidious may regard the malt liquors as vulgar, they are nevertheless one of the best forms in which a mild tonic and stimulant action can be obtained in feeble constitutions when they do not disagree, which is often apt to be the case, the large amount of extractive they contain rendering them very liable to take on an acetous fermentation.

Liqueurs are made by adding sirup to an alcoholic solution of various aromatics, as aniseed. They should only be used in very small quantity. They sometimes contain narcotics, which, added to the alcohol, renders them much more noxious.

The strong liquors, as brandy and whisky, are obtained by

What change does age impress upon wine? Does the stimulating property always depend on the proportion of alcohol? How is port prepared for the English market? What are sacks? Give examples of the sweet wines. Upon what constituent do the malt liquors depend for their tonic properties? What are liqueurs, and how are they prepared?

distilling wines or the products of fermentation of grain, and condensing the alcoholic portions. Brandy is prepared by the distillation of wines. Whisky, according as it is made from rye, or corn, or other grain, receives an appropriate designation. That made from the potato is known as *poteen*. Gin is an alcoholic liquid, to which juniper berries have been added, though the common article often contains turpentine. Rum is obtained by fermenting sugar or molasses. All these strong liquors contain between 40 and 50 per cent. of alcohol, as is shown in the table, page 253, and furnish respiratory food in its most condensed form. They should always be diluted, and used in small quantity.

TOBACCO.

This weed is said to have been first sent to Europe in 1559, and was introduced into England by Sir Walter Raleigh. It was at first much opposed by all the rulers and potentates of Europe, yet, in spite of the philippics of James I., and the excommunications of Urban VIII., its fascinations have enabled it to gain so strong a foothold that it can not now be expelled. On its first introduction into Constantinople, where it is now in universal use, any lover of the weed who was detected in the act of using it was conducted through the streets seated on an ass, with his face turned to the tail of his steed, and his nose transfixed with a tobacco pipe.

The use of snuff is perhaps the least injurious of all the methods of employing tobacco, but when indulged in to excess it is the most disgusting, and liable to produce dyspepsia. It sooner or later deadens the sensitiveness of the olfactory nerve to such an extent that the sense of smell is lost, and the Schneiderian membrane becomes thickened, giving the voice a nasal twang that is very disagreeable to a refined ear. In some parts of the United States the women use snuff to irritate their gums; this offensive practice passes under the designation of dipping.

Smoking is the most universal of all the methods of employing tobacco. When first indulged in it is apt to produce nausea and vomiting. The active principles are *nicotin* and a *volatile oil*. The first is the most volatile, and therefore rises in the smoke and enters the air-passages, where it is absorbed by

How are the strong liquors prepared? How are brandy, whisky, gin, and rum made? When was tobacco introduced into Europe? What is the least injurious form in which it can be used? What is its ultimate effect on the olfactory nerve? What is meant by dipping? What principles of tobacco are volatilized in smoking?

the blood. When a person smokes to excess there is no longer a mere sedative action, but the nervous system is powerfully affected, the hands tremble, and the action of the heart is interfered with, palpitation being induced. It is also stated that the long-continued use of tobacco in any form, and especially smoking, gradually blunts the virile powers, and finally renders men impotent.

Chewing is one of the most offensive methods of employing tobacco, and is very apt to produce dyspepsia.

TRAINING, by which the athlete endeavors to put his body in the best condition for resisting fatigue, renders certain rules compulsory. They are: to retire early; to rise early; to exercise freely in the open air, but not to produce fatigue; to eat moderately of nutritious food; to drink water, or a small allowance of some malt liquor; and keep the mind gently occupied, so as to be free from ennui; and if the person is an inhabitant of the city, he should remove to the country.

In walking 1000 miles in 1000 hours, "Captain Barclay lived as follows. He breakfasted, after returning from his walk, at five in the morning. He ate a roasted fowl, and drank a pint of strong ale, and then took two cups of tea, with bread and butter. His lunch was at twelve, and it consisted, on alternate days, of beefsteaks and mutton-chops, of which he ate a considerable quantity. He dined at six, either on roast beef or mutton-chops, his drink being porter and two or three glasses of wine; and he supped at eleven on cold fowl. He ate such vegetables as were in season, and the quantity of animal food he consumed daily was from five to six pounds."

What is their effect on the system when the tobacco is used to excess? What is the effect of long-continued excess in the use of tobacco? What is meant by training?

LECTURE XLVIII.

HYGIENE OF THE RESPIRATORY SYSTEM.

Changes impressed on the Air by Animals.—The Action of Plants.—The Black Hole at Calcutta.—The Black Assize at Oxford.—Effects of Carbonic Acid on the System.—Inhalation of carbureted Hydrogen.—Fire-damp.—Choke-damp.—Effects of sulphureted Hydrogen.—The Action of Chlorine on noxious Vapors.—Principles of Ventilation.—Methods of Warming by open Fires, by Stoves, and by Furnaces, with the Advantages and Disadvantages of each.—Objections to the Use of Steam-coils in Rooms.—Advantages of the Steam-heating Furnace.

ANIMALS are continually rendering the air impure by the exhalation of carbonic acid, and the whole mass would be gradually vitiated were it not for the action of plants, which undo the work of animals, decomposing the carbonic acid they have expired, setting its oxygen free, and restoring the purity of the atmosphere.

The history of the Black Hole at Calcutta furnishes an illustration of the poisonous character of the emanations from the human body. It was about eighteen feet square, and contained one hundred and forty-six persons; there was only one small window, which was grated, and the atmosphere was very sultry. In less than an hour several of the prisoners were delirious and raved for water, which, when given to them by the sentinels, failed to allay their thirst. In four hours many had died, either by delirium or direct suffocation; in another hour, all except those at the window were either dead or in a violent delirium; and at the close of eleven hours only twenty-three were alive, and these passed through a putrid fever before they finally recovered.

In the Black Assize at Oxford in 1577, a prisoner was brought to the bar after having been confined in a small dungeon for some time. He was placed between the court and an open window, so that the wind carried the emanations from his body toward the judges and jury, and many of them and of the spectators were attacked with putrid fever and died.

The impurity which is generally found in vitiated air is car-

What change do animals impress on air? How is its purity restored? What was the history of the Black Hole at Calcutta? What was the history of the Black Assize at Oxford?

bonic acid; the effects of the inhalation of this gas are pain in the head and singing or buzzing in the ears, loss of voluntary power, and a strong tendency to sleep, disturbed respiration, and palpitation of the heart.

Carbureted hydrogen is also very noxious. It is extensively employed as the illuminating gas of our houses and streets, and is found in coal mines, being known to the miners as *fire-damp*. When mingled with air or oxygen it forms a mixture, which, on the approach of a flame, explodes with such violence as to destroy the mining apparatus, and cause the death of many workmen. The products of the explosion are vapor of water and carbonic acid, which is known to the miners as *choke-damp;* it therefore is unsafe to enter a mine after an explosion until the choke-damp has been removed.

The gas that accumulates in privies, and such receptacles of filth, is sulphureted hydrogen: when respired in the pure state it produces almost instant death, and when highly diluted it is a powerful sedative. The antidote is chlorine; it acts chemically, decomposing the sulphureted hydrogen with great rapidity.

The emanations from the bone-boiling and other establishments where decomposing animal refuse accumulates are composed, to a certain extent, of sulphureted hydrogen and offensive vapors, all of which may be destroyed by the action of chloride and other disinfectants.

The act of respiration is practically beyond the influence of the will. We can not, for any length of time, increase or diminish the rate of respiration; but we can control the nature of the air introduced into the lungs, and substitute for a vitiated gas, redolent with disease, the pure, undefiled atmospheric air, by resorting to a proper system of ventilation.

Ventilation is not generally understood, yet the principle on which it is founded is perfectly simple, and readily applied to any apartment. It depends upon the fact that if a given amount of air is subjected to an elevation of temperature, it increases in volume, becomes lighter, and rises above the cool surrounding air, which flows in to take its place. We may readily satisfy ourselves that warm or hot air rises by ascending to the upper part of a room in which a number of people

What are the effects of the inhalation of carbonic acid gas? What is the effect of the inhalation of carbureted hydrogen? What is the difference between fire-damp and choke-damp? What is the gas that accumulates in privies? How may it be destroyed? Upon what principle are the methods of ventilation founded? How may we satisfy ourselves that warm air ascends?

are assembled, or in which numerous lights are burning, when we find that it is filled with a hot irrespirable gas which almost suffocates us.

In order to allow this vitiated air to escape, an opening should be made in the upper and another in the lower part of the room, through which cold pure air may enter, to take the place of the hot air as it passes out at the upper opening.

It is the neglect to provide the second opening that usually renders attempts at ventilation so unsuccessful, for the warm air can not pass out with any freedom unless there is ample provision for the introduction of fresh air to fill the vacuum caused by the escape of that which has become vitiated.

The openings described above are usually connected with tubes or flues. The flues, intended to afford a passage for the vitiated air, should be built in the chimney, in order that they may be kept warm, and thus insure a steady upward current, which may aid in ventilating the room at all times.

When a room is not provided with flues, excellent ventilation may be obtained by lowering one half of a window, to make an upper opening, and raising the lower half, to provide the lower opening. In a bedroom it is best to adjust the window at the greatest distance from the bed, to avoid the formation of draughts, which may produce rheumatism and other diseases.

The various methods of warming houses are intimately connected with the subject of ventilation. They may be divided into three classes: 1st. By open fires; 2d. By stoves; 3d. By furnaces.

In the method by open fires, either of wood or coal, there is an enormous loss of heat and consequent waste of fuel, more than nine tenths of the heat produced by the combustion passing up the chimney, and only that portion which radiates from the front of the fire being utilized. Another disadvantage is the production of draughts or cold currents, which flow in through every cranny and crevice to fill the vacuum caused by the passage of the heated air up the chimney, and which must exist in order that the combustion may go on.

The advantages are, 1st. A partial ventilation, since the opening of the chimney is in the lower part of the room; 2d. The warming of the air without burning the fine organic dust

How many openings are required in order to ventilate a room, and where should they be situated? How may we ventilate a room that is not provided with flues? What methods are employed in warming houses? What are the objections to the method of warming by open fires? What are the advantages attending their use?

which floats in it; but these are almost counteracted by the fact that one is obliged to keep continually revolving in front of the fire in order to be warmed equally.

In the second method the fuel is economized, and, if a long pipe is attached to the stove, the greater portion of the heat is utilized; but the disadvantage is the burning and charring of the filaments of organic matters that float in the air of the room, which renders them more irritating to the delicate mucous membrane of the lungs. The ventilation obtained by the stove is also imperfect, since it draws the air from the parts adjacent to the floor, and allows the noxious gases to accumulate. It also has a tendency to render the air very dry, which should always be counteracted by keeping a vessel of water on the stove, that moisture may be supplied as fast as it is required.

The objection regarding draughts also exists in the use of the stove, but to a greater extent. The temperature of a room warmed by a stove is higher than that of one warmed by an open fire; since, therefore, the variations and contrasts are greater, the consequences are more severe.

Under the method of warming by furnaces we may classify the ordinary hot-air furnace, the coil of steam pipes in a room, and the hot-water or steam-heating furnace. The ordinary hot-air furnace has many advantages over the method by open fires and stoves; among these, the chief is the avoidance of draughts, the tendency of the furnace being to condense air into the room, and so destroy all opportunity for the formation of draughts by keeping continuous currents of warm air flowing out at every crevice.

The hot-air furnace also provides the means of obtaining a most thorough ventilation by continually renewing the air contained in the apartment. The only valid objection to this system of warming is the liability to render the air irritating to the lungs by burning and drying it. This may be avoided to a great extent by proper attention to the condition of the furnace, and supplying the hot-air chamber freely with water in shallow pans, in which cloths are suspended, to provide an extended surface from which evaporation may take place.

The use of steam pipes in rooms for the purpose of warming is the worst of all methods employed. It is true it is conven-

What is the advantage gained by warming with a stove? What are the disadvantages of the second method of warming? How should the drying of the air be remedied? What are the advantages attending the use of the hot-air furnace? What are the disadvantages? How may they be rectified? What is the worst system of warming?

ient, economical, and cleanly, but all these advantages are nullified by the absolute want of ventilation which attends this system. The air of the room is never changed, but is warmed over and over again, rising to the top of the chamber, and then passing over the heater when it has become cool, to be again heated and breathed, so that on entering such an apartment one is nauseated with the foul odors that pervade it if it contains many people.

This method may answer very well, and be used with impunity in stores and shops where the doors are being continually opened and fresh air introduced, but it should be abolished from hospital wards and small bedrooms as being poisonous, unhealthy, and not to be tolerated.

The last method, by the hot-water or steam furnace, in which the air is warmed in a chamber filled with pipes, through which steam or hot water is passing, is the best of all the systems employed, since it combines all the advantages of the hot-air furnace in regard to the avoidance of draughts, and at the same time warms the air without scorching it.

We can not leave the consideration of the subject of ventilation without drawing attention to the manner in which the human system gradually adapts itself to the increasing foulness of a confined volume of air. An example is afforded by the manner in which a number of men will congregate together in a room void of all means of ventilation, and continue to smoke and drink for hours, with the windows and doors closed, until the accumulation of foul gases is so great as to produce almost immediate faintness in a person who enters the apartment from the exterior fresh air, while those who have been present from the commencement of the orgie seem to be unaffected.

Though the system may adapt itself to the use of a vitiated atmosphere for a time, it is evident that it must result finally in reducing its tone and vitality, and favor the development of many diseases. It is doubtless owing to the unavoidable impurities in the air of great cities that the inhabitants of such places do not live as long as those who reside in the country, and breathe the pure fresh air of the woods and fields.

Under what circumstances may the method of warming by steam coils in rooms be employed? What is the best method of warming? Can the system adapt itself to the use of noxious gases? What is one of the chief causes of the shortness of life in cities?

LECTURE XLIX.

DISINFECTANTS AND MALARIA.

Substances employed as Disinfectants.—The Peloponnesian Plague.—Action of Charcoal.—Malaria or Miasma.—Circumstances under which it is produced with greatest Virulence and Rapidity.—Is not the Result of Animal or Vegetable Decomposition alone.—Evils attending the close Proximity of Trees to a Dwelling.—Selection of a Building Site.—Relative Power of dry and moist Air to convey Malarial and other Emanations.—Explanation of the Appearance of Malarial Fevers on high Ground.—Means for warding off the Access of Malaria.—Effect of Change of Air on the System.—Action of Winds.—Time at which a Consumptive should Travel.

When the air of a house, or given locality of limited extent, has become impure from the presence of decaying animal or other organic matter, it may often be purified by the use of disinfectants, such as carbolic acid, free chlorine, the chloride of lime, or the solution of chloride of soda. On the great scale, charcoal is the best disinfectant, as was demonstrated by the fact that the great fire in London put a stop to the plague which was raging at the time the fire originated. It is also the oldest known disinfectant, for we read that in the year B.C. 430, when, by the Peloponnesian War, Athens was crowded with fugitives from the cities in the vicinity, a great plague broke out, which Hippocrates stopped by causing immense fires to be lighted in all parts of the city and its vicinity.

The disinfectant power of charcoal is probably due to the property it possesses of absorbing different gases. Of ammoniacal gas it will take up ninety times its own volume; of hydrochloric acid gas, ninety-five; and of other gases various proportions. Since the deleterious poisons of fevers and plagues exist in the gaseous state, or are disseminated through the air in an exceedingly fine state of subdivision, it is reasonable to suppose that charcoal removes them by absorbing them into its pores, just as it absorbs hundreds of other gases and vapors.

The terrestrial emanations or malaria, which are generally supposed to produce fever and ague only, but which really pos-

Name the substances employed as disinfectants. How did Hippocrates stop the plague that followed the Peloponnesian War? To what property of charcoal is its disinfectant power due? What name is given to the terrestrial emanations that produce fever and ague?

sess the power of modifying, and even of originating many of the diseases to which man is heir, and giving them a periodic character, are still enveloped in mystery. They are generally produced in marsh districts, but they also appear at times in volcanic regions which are perfectly free from marshes, and do not even contain springs or any other natural waters. It is supposed by many that the malarial poison is the product of the decomposition of vegetable substances; but, if the presence of vegetable matter is necessary, how are we to account for its appearance in volcanic regions where there is no vegetable matter for miles? In marsh lands the malarial poison is most intense in its virulence when the water has all disappeared, and the bed of the marsh so dried up that all decomposition must have ceased; and experience has taught that if, in the very worst regions, the ponds and rivulets are kept full of water, so that their beds are not exposed, there is very little danger. There can be no fouler odor or miasm than that which emanates from the hold of a sugar-ship, and yet it has never been known to create miasmatic fever. We might continue to cite numerous other instances to demonstrate the fact that the malarial poison is not the result of vegetable decomposition alone, but, as our space will not admit, we pass to the consideration of the theory that it is the product of animal putrefaction.

If miasmatic fever was caused in this manner, it should be most intense in the vicinity of the establishments occupied by "knackers," who are engaged in converting dead animals into such manufactured articles as ammonia, but we do not find that even the "knackers" are predisposed to malarial diseases; on the contrary, they are usually strong and healthy in spite of the vile odors among which they live, and many reach the advanced age of eighty. An epicure will eat the flesh of a bird that is putrid, and yet no symptoms of malarial fever appear. Medical students will breathe the offensive air of the dissecting-room for months with perfect impunity. We therefore are driven to the conclusion that malarial fevers are not caused by animal exhalations alone.

From the statements made in the preceding paragraphs, we see how imperfect our knowledge of the origin of miasmatic fevers is, yet there are certain well-established facts regarding them which are presented in the following quotation from one

In what kind of soil do they prevail to the greatest extent? Is a marshy soil necessary to the development of malaria? Is the malarial poison the product of vegetable decomposition alone? At what time does marsh land evolve malaria with the greatest rapidity? Is malaria produced by animal decomposition?

of our most distinguished medical authors: "It may be stated as a general rule that houses in confined, shaded situations, with damp courts or gardens, or standing water close to them, are unhealthy in every climate and season, but especially in a country subject to intermittent fevers, and during the summer and autumn. In our own country nothing is more common than to see houses built in very unhealthy situations, a few hundred yards distant only from a good one. Again, houses in places otherwise unexceptionable are often so closely overhung with trees as to be rendered far less healthy residences than they otherwise would be. Thick and lofty trees in the immediate vicinity of a house tend to maintain the air in a state of humidity by preventing its free circulation, and by obstructing the free admission of the sun's rays. Trees growing against the walls of houses, and shrubs in confined places near dwellings, are injurious also, as favoring humidity; at a proper distance, on the other hand, trees are favorable to health. On this principle it may be understood how the inhabitants of one house suffer from rheumatism, headache, dyspepsia, nervous affections, and other consequences of living in a confined humid atmosphere, while their nearest neighbors, whose houses are more openly situated, enjoy good health; and even how one side of a large building, fully exposed to the sun and to a free circulation of air, may be healthy, while the other side, overlooking damp shaded courts or gardens, is unhealthy. The exemption of the central parts of a large town from these fevers is partly explained by the dryness of the atmosphere which prevails there, and the comparative equality of the temperature. Humid, confined situations, subject to great alternations of temperature between day and night, are most dangerous. Of all the physical qualities of the air, humidity is the most injurious to human life; and therefore, in selecting situations for building, particular regard should be had to the circumstances which are calculated to obviate humidity either in the soil or atmosphere in every climate. Dryness, with a free circulation of air, and a full exposure to the sun, are the material things to be attended to in choosing a residence. A person may, I believe, sleep with perfect safety in the centre of the Pontine Marshes by having his room kept well heated by a fire during the night."

In what situations is malaria usually found? Is a house healthy when trees are close to it? How do they act? Are trees at a distance unhealthy? What points should be particularly noticed in selecting a building-site?

As odorous vapors and gases are conveyed to a greater distance by moist air than by that which is dry, so, during the day, the miasmatic exhalations are conveyed in the aqueous vapor that arises from the soil in which they have been generated; and at night, when the vapors condense, the miasmatic poison is also deposited, and accumulates in the strata near the surface of the earth. The lower stories of a building are therefore rendered very unhealthy if the windows are allowed to remain open during the night, while the windows of the upper stories may be left open with impunity, since all the malarial emanations are condensed in the lowest strata of the atmosphere. In all dangerous districts it is unsafe to sleep on the lower stories of a house, and it is best in all localities to have the bedrooms on the second or third story.

By the action of winds, miasmatic poison may be carried to considerable distances; and it is found, as we might naturally expect, that any thing that tends to break the force of the wind, or turn it from its course, is a protection against malaria. The presence of a high wall or screen of woods is often an impassable barrier to such emanations, and even a low hedge of bushes will frequently turn them aside, and render localities healthy which would otherwise be uninhabitable. So perfect is the protection afforded by fringes of bushes and forests, that some suppose the leaves possess an affinity for the malaria, and filter it out from the air in which it is being conveyed.

CHANGE OF AIR.

Our physicians frequently prescribe a change of air as a remedial agent; it is also one of the best hygienic stimulants that can be employed. When the mind and body are reduced by overwork, a slight change from the city to the country, or even from the country to the city, will often produce the most marvelous improvement in the general health, and reinvigorate all the organs of the system to such an extent as not only to ward off an attack of illness, but even enable us to undergo increased labor, by furnishing a new lease of life and vigor.

The advantages of a short sojourn at any of our watering-places are well known, but the majority of people seem to think they are chiefly due to the nauseating waters that are always in the fashion at such places, whereas, in reality, the

Does moist or dry air convey odorous emanations to the greatest distance? Why are the lower stories of a building the most unhealthy? How may we explain the appearance of malarial fevers on high ground? How may the access of the malarial poison be hindered? What is the effect of change of air on the system?

salutary results are in a great measure the effect of change of air, and the continued succession of gay scenes and pleasures into which the invalid is obliged to enter to a greater or less extent, and which, by diverting his mind, give it rest, so that it can recuperate; and with the improvement in the tone of the nervous system, there is necessarily improvement in the general health.

The effect of winds is very similar to that of change of air, for they substitute a pure atmosphere for that which is stagnant and laden with poisonous emanations.

When the system is already prostrated by a slow, lingering disease, like consumption, great care should be taken in the selection of the locality to which the sufferer should go. It is a very common idea that a trip to Southern Europe, and a sojourn of a few months under the soft Italian skies, is one of the best things that can be done; but, though it may be of advantage in the earlier period of the disease, it too often hastens the final catastrophe in the latter stages, the separation from the comforts of home, and the absence of those who could cheer and comfort the sufferer producing more harm than the change of air does good.

Certain islands have been long recommended as combining many advantages for consumptives; among them we may mention Madeira and the West Indies. In many cases great advantages are derived from a sojourn at these places in the winter; but the evil consequences of removal in the latter stages of consumption are marked in the church-yards by the tombstones that indicate the resting-places of those who sought relief when it was too late.

To what causes may we attribute the improvement produced by a sojourn at a watering-place? How do winds act on the atmosphere? At what period of consumption should the patient travel?

LECTURE L.

HYGIENE OF THE SKIN.

Effect of sudden Changes of Temperature on the Mortality Lists.—Symptoms of approaching Death from Cold.—Southern Nations resist Cold better than Northern.—Time at which it is best to go into the cold Air from a heated Room.—Effect of Moisture on the System.—Effect of desiccated Air on the Mucous Membrane of the Lungs.—Great solvent Action of moist Air on Emanations.—Application of Heat to frozen Limbs.—Chilblain.—Effect of Climate on Nations.—Effects of Light and Electricity on the Body.—Conveyance of Miasmatic Emanations by damp Air.—Effects of Winds on endemic and epidemic Diseases.

Extremes of temperature are very unfavorable to life, the intense cold of winter increasing the mortality list among the aged, while the heats of midsummer are especially fatal to young people and children. Baron Larrey, who was Napoleon's surgeon-in-chief during his campaign in Russia in 1812, states that during the nights of the 8th and 9th of December the thermometer touched —27° and —32° Fahrenheit, and the men and horses were struck with stupor if they took the slightest repose, and died in great numbers. Many of the soldiers died while on the march: in these instances the countenance first became pale, and assumed an idiotic expression; speech was imperfect and labored; the eyesight was dimmed, and often entirely obscured, but they continued to march along in column, supported by their comrades; gradually the movements of the muscles became more and more feeble; they staggered as though they were inebriated, and, leaving the column, soon fell into the snow, whence they could not rise, but, being attacked by an overwhelming stupor, died in a few minutes.

The same authority states that the soldiers from Southern Europe withstood the cold far better than those from Germany and Northern Europe; the former having a higher hygienic morale than the latter, who were specially liable to nostalgia, or home-sickness, which is doubtless caused by the domestic habits of the Germans, and all races that live in cold climates, and which are powerfully influenced by their home associa-

What is the effect of cold and hot weather on the mortality lists? What are the symptoms of the approaching destruction of life by cold? What nations resist cold best?

tions, since they are obliged to rely to a greater extent on their families for their happiness and comfort.

Various opinions are held regarding the effect of sudden changes of temperature on the system, and many persons habitually wait to get cool before they pass from the hot atmosphere of a ball-room to the cold external air, fearing that the sudden change will be injurious. It is true that there is serious risk in exposing the body to a great decrease in temperature, often in the winter from 80° in the ball-room to near the zero of our scale in the open air; but we must also remember that if we pass into the air while the excitement still continues, the powers of resistance are greater than when all such stimulus is lost by a continued lingering in the dressing-room in order to allow the temperature of the body to fall. We can not, therefore, doubt that it is best, on leaving the ball-room, to dress warmly, with as much haste as possible; and if we are so fortunate as to have cheerful company on the way home, there is but little danger to be feared. In no part of the world is the effect of excitement in enabling the system to resist cold better known than in our own vicinity. How rare it is for any one to take cold when they have indulged in a sleigh-ride; the excitement of the rapid motion; the joyous jingling of the bells; the merry song and merrier laugh being contagious, and producing a degree of stimulation that is a protection against the evil consequences of what would otherwise be a dangerous indulgence.

Though sudden changes from heat to cold can be borne with comparative impunity, those from cold to heat are very apt to give rise to injurious consequences; and when the body, or any part of it, has been chilled, the application of heat should be gradual and cautious. The chilblain is not produced by the action of cold, but by the effect of heat on the chilled extremity. Sometimes the inflammation runs so high as to terminate in gangrene: such evil consequences may be avoided by applying heat gradually, the best method being by friction with some cold substance. It is said that in the north of Europe it is not an uncommon incident for a traveler to be surprised in the winter season by a stranger rushing up to him with a handful of snow, and proceeding to rub his nose in the most discourteous and vigorous manner, in order to restore the circula-

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At what time is it best to return home from a ball? Why is it that people so rarely take cold while sleigh-riding? Is a sudden change from heat to cold as dangerous as one from cold to heat? How should heat be applied to a frozen extremity?

tion in the frozen feature. Even in New York we occasionally hear, in very cold seasons, of persons who have lost their feet or hands by applying heat incautiously to these members when they have been thoroughly chilled or even frozen.

In the temperate regions the changes are more frequent and violent than in other climates, and we find the impress of the climate stamped on the character of the nations of the temperate zone. As their climate is variable, so they are subject to rapid variation in thought and action. They are compelled, by the exigencies of nature, to meet sudden variations with suitable remedies, and, from a mere attention to the means required to render existence tolerable, they by degrees carry a system of observation and experiment into all their affairs, and pass their time in unceasing activity, while the inhabitant of a more favored clime is wasting his life away in dreamy idleness.

It is not only necessary that fresh air should be freely and abundantly supplied, for light is also essential to the proper development of the body, as any one may satisfy himself by comparing the blanched, sallow, deformed child who works in mines, with the robust, ruddy, well-formed little one who has his home among the green fields, and spends hours playing in the sunshine.

The electric state of the atmosphere also influences the system, and though we may not be able to trace its method of action, we all know how the physical and mental sensations are influenced by an approaching storm. The effects of the sudden discharge of a large amount of electricity on or into the body is also well known to result in almost instantaneous death, and the bodies of persons who have been struck by lightning undergo decomposition more rapidly than those of persons who have died from other causes.

The hygrometric condition of the air also exerts a powerful influence on the condition of the system. Air at all times contains moisture, which may be detected by bringing it in contact with a cold surface, when the vapor of water immediately condenses, and covers the surface, as, for example, a pitcher of ice-water, with drops of moisture.

As we have demonstrated in Lecture XXI., a large proportion of the egesta escapes from the body in the form of insensi-

How does the climate of the temperate zone affect the inhabitants of that region? How does light affect the body? What is the effect of a sudden discharge of electricity on the body? How does the hygrometric state of the air affect the body? How is the presence of moisture in the air detected?

ble perspiration or vapor. When the air is laden with moisture it can not so readily take up the vapor from the skin, and we consequently feel the heat more severely than when the dew point is low, and there is less interference with the vaporization of water from the system. Under these circumstances there is a tendency to the accumulation of effete materials in the body, and consequently a greater liability to disease.

Gay-Lussac found that at great altitudes the proportion of moisture in the air steadily decreased, and respiration is attended by disagreeable sensations, caused, as he supposes, by the desiccating action of the dry air on the lungs. A moist air has a greater solvent action over various mineral, vegetable, and animal substances than a dry one. In burning lime the workmen find that the carbonic acid gas is displaced with greater facility on a damp day than on one which is dry; they consequently place in the ash-pit of the furnace a pan of water, the steam from which, passing into the fire, aids in expelling the carbonic acid. The mineralogist avails himself of the same property of moisture when he causes the various clay-like bodies to give out their peculiar odor by breathing on or moistening them; and all must have noticed the great distance to which foul odors are conveyed in a fog, or just before a rain-storm, when the air is highly charged with moisture. The malarial emanations from the earth are also in many instances carried to great elevations by the moisture that has been evaporated by the sun's rays, and after passing over many miles of level land without producing any evil consequences, are finally deposited on the high lands from the water that is condensed in these regions by the decreased temperature that prevails, and give rise to agues and other malarial diseases. This is so well known that the inhabitants of malarial districts regard the time at which the dew falls as the most dangerous, and carefully abstain from exposing themselves to its action.

It is said that in Africa, when the dry wind blows from the interior to the ocean, not only do the ordinary endemic diseases leave them, but those which are epidemic in their character, and even contagious diseases, as small-pox, also disappear. If this is true, and there is no good reason to doubt the veracity

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How does the air of great altitudes affect the respiratory apparatus? What was Gay-Lussac's theory of its mode of action? Does moist or dry air possess the greatest solvent power over emanations? Why is water placed in the pit of a lime-kiln? Give illustrations of the power of moist air to convey odors with greater facility than dry air. How do malarial emanations reach great elevations? At what time of the day is malaria most dangerous? What is the effect of winds on endemic and epidemic diseases?

of the statement, it would appear that the humidity of the air influences the properties of diseases, rendering them more dangerous in some seasons than in others.

LECTURE LI.

HYGIENE OF THE SKIN, *Continued.*—BATHING.

Conditions essential for the proper Conduction of the Action of the Skin.—The Roman Thermæ.—Action of pure Water on the Skin.—Use of Soap.—Abuse of Soap.—Cold Plunge-bath.—The Chill or Shock.—Use of the Cold Bath for Infants.—Conditions of the System in which Cold Baths should not be used.—Tepid Baths.—Adaptation of Tepid Baths to various Constitutions.—Warm Baths and their Action.—Hot Baths and their Action.—Flagellation.—Shampooing.—Turkish Bath.—Sea Bathing.—Effects of the long-continued Application of Water to the Skin.—Evil Consequences attending the sudden Stoppage of the Action of the Skin.

The skin being one of the great excretory organs of the body, it is necessary that its function should be discharged in a proper manner, in order that the system may be relieved of the deleterious substances which escape through the cutaneous glands. The hygienic conditions to be observed in order to accomplish this result are a due regard to cleanliness, and the proper protection of the body by suitable clothing.

It is said that we may judge of the degree of civilization a nation has reached by finding the per capita amount of soap it consumes. This may be very true as regards civilization, but it is not necessarily the case regarding health, for we may abuse the proper use of soap and of water to such an extent as to produce injurious consequences.

Among the Romans the bathing establishments were very magnificent, and contained the *frigidarium*, or cold—the *caldarium*, or hot—the *tepidarium*, or warm—and the *vaporarium*, or vapor bath. They were also provided with the *coxæluvium*, or hip bath; the *manuluvium*, or hand bath; the *pediluvium*, or foot bath; the *capituluvium*, or head bath; the *semicupium*, or half body bath. We employ, in addition, the shower-bath, electric bath, the dry bath of hot ashes and sand, and finally the animal bath, which consists in wrapping the warm skin of a recently-killed animal around the body. In their great *thermæ*, or baths, the Romans also had the *apoditerium*, or dressing-

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What were the divisions in the Roman thermæ?

rooms; the *unctuarium*, or perfuming-room; and a host of servants, who performed special duties in the various apartments. So solid and durable were the thermæ, that in many cities they constitute the best preserved and most interesting ruins; they have also yielded to the modern museums many of the finest specimens of ancient art, the majority of the famous pieces of sculpture and mosaic having been found among the débris of the Roman baths.

Water is the proper fluid to be used in washing the surface of the body, for it removes the soluble excretions of the cutaneous glands. Soap is also admirably adapted to the removal of dirt of every variety that may have accumulated on the hands or feet; but if it is used too freely on the general surface of the body, it dissolves the oily exudation of the sebaceous glands, which is required to enable the skin to retain its flexibility and softness. The external epithelial cells are also removed too rapidly when soap is used in excess, and consequently the skin is not properly protected; it becomes subject to greater congestion in order to reproduce the cells and oils that have been abstracted, and is therefore more liable to cause disease in the system when it is suddenly subjected to the action of cold or draughts.

The cold plunge or shower-bath is the best form in which water can be applied to the whole surface of the body, when the system can bear the shock; it then removes the soluble salts that have been delivered on the surface by the sudoriparous glands, accustoms the skin to the sudden application of cold, and gives a healthy stimulus to its action and to the whole system.

Since the temperature of wells and springs is usually below 60° Fahrenheit, and that of the human body is about 100°, it is evident that the cold bath, in its first application to the surface, must abstract a large amount of heat. The effect of this loss of caloric is the production of a chill or shock, in which the skin is shrunken and bloodless, the internal organs overloaded with blood, the nervous centres rendered torpid and sluggish, and a general sedative action produced. If, on leaving the bath, the person steps into a warm room, and the body is quickly rubbed dry, reaction comes on; but if the bather is

What is the action of pure water on the skin? What is the object of using soap? What is the effect of employing an excess of soap? How does the cold plunge-bath act? What is the temperature of spring water compared with that of the skin? What conditions attend the production of a chill or shock? How should the reaction be brought on after a cold bath?

in the open air, and especially if the water is allowed to evaporate from the surface in a current of cool air or wind, the chill produced will often overpower a weak person. The temperature and circumstances under which a bath is taken must therefore be modified to suit the condition of the bather, and cold baths should not be employed unless reaction comes on in a satisfactory manner when the body is speedily rubbed dry after the bath.

Many persons think that young infants should be hardened by giving them cold baths and exposing them to cold air. If a child is strong and healthy it will stand a degree of exposure with impunity, but if it is weak or puny such treatment is criminal. In the words of John Bell, "Cold bathing of tender infants, without regard to constitution and temporary changes of health, acts in a manner nearly analogous to the test of nitric acid on the metallic alloys: if gold be in them it remains untouched, and is exhibited in its native brightness; the other metals are corroded and dissolved. So with the cold bath: the feeble and valetudinary sink under its use, while the strong and robust are exhibited in a more distinct point of view, and are even benefited by their acquiring a habit of endurance of cold."

In those who are suffering from acute cutaneous eruptions the cold bath will often prove injurious. Those persons who are subject or liable to sudden internal congestions should avoid the use of the cold bath. Females also, at the time of the menstrual discharges, should, as a rule, be very careful in the exposure of their bodies to the action of cold.

When the cold bath is followed by a healthy glow over the whole body it may be freely used; but if it produces a chill, which continues even though the body is well rubbed, it should be avoided, and tepid or warm baths substituted. Tepid baths are sometimes debilitating in their action; but since there are certain constitutions which can not bear the sudden application of cold, the use of warm water is sometimes necessary for the purpose of cleansing the surface of the skin. When tepid baths are employed, the time the person remains in the bath should not be more extended than is required to wash the surface of the body.

Is the indiscriminate use of cold baths for young infants justifiable? Should the cold bath be used by persons suffering from acute eruptive diseases? Should it be employed by women when they are menstruating? Under what conditions should the cold bath be used? How do tepid baths act? How long should a person remain in a tepid bath?

The tepid bath should have a temperature from 75° to 90°; it is admirably adapted to constitutions in which the shock of the cold bath is injurious. It may be adjusted to all constitutions by first immersing the body in water which is very near the temperature of the system, and then cooling it five or ten degrees, and repeating the immersion; and, if it is desirable, the same process may be again repeated.

The warm bath should have a temperature of about 95°; when the circulation is languid the temperature may be two or three degrees higher, and if it is active it may be a few degrees lower. It is especially grateful when the body is exhausted by the fatigue of labor or travel, since it removes the accumulated secretions of the skin, and reinvigorates the system without subjecting it to a shock. For old people and infants the warm bath is preferable to the cold, and the dryness of skin from which many old people suffer is often relieved by using the warm bath two or three times a week.

The effect of the warm bath on the organs of circulation and respiration is sedative, the rate of pulsation and respiration being diminished, and the capillaries of the skin relaxed, the blood flowing with greater ease and freedom to all parts of the system.

In the hot bath the temperature of the water is above 98°; its action is stimulating, since it adds to the heat of the body, and excites the circulatory and nervous systems to an extent that is often injurious. The plethoric condition of the body under the excitement is shown by the swelling of the fingers, the rings that are worn producing an uncomfortable degree of pressure, and such symptoms as vertigo, palpitation, and fainting being often superinduced; these pass away on leaving the bath, and are followed by a free perspiration and a sense of exhaustion.

In some countries certain manipulations are considered to be necessary accessories to a bath. The Russians submit the body to a course of flagellation with birch twigs in order to excite the cutaneous capillaries. Frictions are employed by others, but the operation of shampooing is perhaps the most complex; it was originated by the Hindoos, and is described as follows: "One of the attendants on the bath extends you upon a bench, sprinkles you with warm water, and presses the whole body in

What should be the temperature of a tepid bath? How may it be adjusted to various constitutions? What should be the temperature of the warm bath? What is its effect on the system? What is the temperature of a hot bath? How does it act? What state of the system follows the hot bath? What is flagellation? What is shampooing?

an admirable manner. He cracks the joints of the fingers and of all the extremities. He then places you upon the stomach; pinches you over the kidneys; seizes you by the shoulders and cracks the spine by agitating all the vertebræ; strikes some powerful blows over the most fleshy and muscular parts; then rubs the body with a hair glove until he sweats; grinds down the thick, hard skin of the feet with pumice-stone; anoints you with soap; and, lastly, shaves you, and plucks out the superfluous hairs. This process continues for three quarters of an hour, after which a man scarcely knows himself; he feels like a new being." In Eastern countries, where the use of the Turkish bath prevails, the bather is subjected to all the above processes, and at the close of the operation the surface of the body is anointed with some oleaginous substance, to protect the skin from the consequences of such harsh treatment.

Sea-bathing differs from the fresh-water bath not only in the presence of saline materials in the water, but also by the exciting circumstances by which it is surrounded. To use the words of Bell: "If we merely had regard to the temperature of sea-water, we should consider immersion in it as simply cold bathing; but there are circumstances connected with the act which modify materially its effects. Sea-bathing is usually preceded by some exercise, a walk or ride to the beach; it is accompanied by some muscular exertion—struggling against the waves, or, in the more robust, by attempts to swim. With others, again, the whole affair is attended by a dread of danger, which powerfully affects the nervous system, and causes hurried breathing, palpitation, and increased rapidity of the circulation, all of which tend to change materially the character of the bath, and render the bath in the air, whether in the sea, or in river or lake water, very complex in its action when compared with the ordinary house bath."

In order to reduce the effect of the shock in the bath in the open air, it is best to immerse the whole body as quickly as possible; in this manner the uncomfortable sensations that attend the gradual immersion of the body are avoided. The best time to bathe is also a matter of interest; the bath before breakfast is no doubt the most wholesome, since at all other periods the stomach is more or less engaged in the process of digestion. The length of time a person should remain in the

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What is the final operation in the Turkish bath? How does sea-bathing differ from the fresh-water bath? How may the shock be reduced in bathing? What is the best time to bathe?

water is a question that must be determined by every one for himself, but, as a rule, five or ten minutes is sufficient, and the body should be well rubbed with a rough towel on coming out.

The long-continued application of water is apt to result in reducing the vitality of the skin to so low a degree as to cause numerous ulcerations and boils. In some people such eruptions may remove deleterious substances from the body, but the experience of the majority shows that they are the product of the debilitating action of the water on the glands of the skin, and unless the abuse of that liquid is discontinued the most disagreeable consequences may ensue.

In some persons the glands in the armpits and other parts of the body secrete a fluid possessing a disagreeable odor, and it often happens that the attempts to remove it by the free use of soap and water result in its increased production, and the secretions are rendered more offensive.

It must not be supposed that we object to the proper use of water in what has been said in the preceding paragraphs; it is only intended to draw attention to its abuse, and to the peculiarities of the systems of some individuals, for the majority of men are benefited by the use of daily baths. It is a matter of which every individual must judge for himself, and determine, by experiment on his own person, how often and what variety of bath should be employed.

Sudden variations in temperature and in the dew point are apt to check the action of the skin; draughts of air from small crevices produce the same result, while a strong wind is often harmless. The sudden stoppage in the action of the skin causes the effete materials which it is its function to excrete, to accumulate in the system, until finally they seek an exit through some other channel, such as the lungs or kidneys, and, acting as irritants to these organs, produce the numerous inflammations which arise from exposure and cold.

How long should a person remain in the water? What is the effect of the long-continued application of water to the skin? What is the effect of the sudden stoppage in the action of the skin? What causes affect the action of the skin?

LECTURE LII.

HYGIENE OF THE SKIN.—CLOTHING.

Materials employed in the Manufacture of Clothing.—Experiments of Davy on the conducting Power of various Textures.—Influence of Packing on the conducting Power.—Summer and Winter Clothing.—Use of Flannel.—Exemption of the ancient Romans from Malaria.—Captain Murray's Experiments with Flannel.—Use of Flannel by the Aged and Infirm.—Use of Stockings.—Changing of Under-clothing.—Clothing should be well aired.—Scotch Method of airing Clothing.—The Cut or Shape of the Clothing.—Adaptation of the Shape to the Climate.—Use of Corsets.—Experiments of Dr. Stark on the absorptive Power of Textures of different Colors.

In order to enable the skin to continue its function with regularity, it should be protected from sudden changes of temperature by means of suitable clothing. The materials employed for this purpose are linen, cotton, wool, and silk.

Sir Humphrey Davy made a very interesting series of experiments to determine the conducting power of these materials. The method he employed was to fill a glass flask with the substance under examination, and, introducing a thermometer with its bulb resting at the centre of the flask, the arrangement was then immersed in a vessel of boiling water, and the time required to raise the index liquid of the thermometer a given number of degrees determined. Submitting various textures to this test, he found that linen was the best conductor, then cotton, wool, and silk, in the order mentioned, silk being the worst.

Davy also found that the closeness of packing influenced the conducting power by entrapping a greater or less amount of air in the meshes of the tissue. When it was tightly packed the conducting power was improved, while loose package diminished the conductibility. In weaving cloth the textures intended for winter use should therefore be loosely woven; those to be employed in the summer should be closely woven. Linen and cotton goods, being the best conductors, are suitable for

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What materials are employed in the manufacture of clothing? Describe the experiments of Davy on the conducting power of different tissues. What is the order of the conducting power of different tissues? What is the influence of variation in package on conducting power? How should summer goods be woven?

summer use in hot climates, while woolen and silk goods should be employed in the winter season in cold climates.

Many discussions have from time to time arisen as regards the healthfulness of various textures used as under-clothing. The oldest, most enduring, and perhaps the best, is linen. We find it mentioned in the earliest works, and it is even now found in the cerements enveloping the mummies that were interred thousands of years ago in the tombs of ancient Egypt.

It is not only necessary that the body should be protected from the direct action of the variations in the seasons, but care should be taken not to expose it when it has been heated by violent exercise. During the continuation of the exercise it may be exposed freely; but when exercise has ceased, and it is bathed with perspiration, and the skin is congested, it should be protected from the injurious action of draughts and currents by some suitable covering.

When the occupation of the individual subjects him to frequent changes of temperature, experience has taught us that the best material to use next the skin is wool in the form of flannel; it protects the body from the sudden changes to which it is liable, and absorbs the perspiration as fast as it is secreted without producing a disagreeable sensation of chilliness, as is the case with linen and cotton.

By some the use of flannel next the skin is held in such high esteem that they have even attempted to show that in past times the Romans suffered less from the malarial fevers because they incased their bodies in warm materials made of wool, and it has been thought that the sheep and other animals that feed during the night on the Campagna owe their freedom from malarial disease to the dense covering of wool or hair with which Nature has provided them.

The advantage of wearing wool next the skin is properly appreciated among army and navy officers; and Captain Murray, of the British ship Valorous, relates "that he was so strongly impressed, from former experience, with a sense of the efficacy of the protection afforded by the constant use of flannel next the skin, that when, on his arrival in England in December, 1823, after two years' service amid the icebergs of the coast of Labrador, the ship was ordered to sail immediately for

What is the best material to wear next the skin? Should the body be exposed while the skin is congested? What is the best material to wear next the skin when the body is obliged to be submitted to sudden changes of temperature? What opinions have prevailed regarding the exemption of the ancient Romans from malarial fevers? What was the experience of Captain Murray regarding the use of flannel in hot and cold climates?

the West Indies, he ordered the purser to draw two extra flannel shirts and pairs of drawers for each man, and instituted a regular daily inspection to see that they were worn. These precautions are stated to have been followed by the most happy results. He proceeded to his station with a crew of one hundred and fifty men; visited almost every island in the West Indies, and many of the ports on the Gulf of Mexico; and, notwithstanding the sudden transition from extreme climates, returned to England without the loss of a single man, or having any sick on board on his arrival." He also adds "that every precaution was used, by lighting stoves between decks and scrubbing with hot sand, to insure the most thorough dryness, and every means put in practice to promote cheerfulness among the men. When in command of the Recruit gun-brig, which lay about nine weeks at Vera Cruz, the same means preserved the health of his crew, when the other ships of war anchored around him lost from twenty to fifty men each; and although constant communication was maintained between the Recruit and the other vessels, and all were exposed to the same external causes of disease, no case of sickness occurred on board the Recruit."

When flannel is first put on it often causes an exceedingly unpleasant itching, which may be avoided by wearing linen or cotton under it; but the practice should be avoided if possible, for it seriously interferes with the hygienic properties of the flannel. Aged and infirm people should wear it all the year; and if those who are subject to rheumatism, or predisposed to grave pulmonary disease, would adopt the same practice, it would be greatly to their advantage.

Stockings, though a modern discovery, have become an indispensable article of clothing for adults. The singular effects of exposure of the feet to cold and wet are known to all, yet how careless most people are in this particular, and how bitterly they regret their neglect when a severe catarrh or rheumatism is the penalty which outraged nature exacts. In childhood many severe attacks of disease might be averted by keeping the feet warm and dry; and as middle and old age approach the precaution becomes more necessary, for the powers of the system to throw off disease are less, and, since prevention is always better than cure, it is best to don the winter woolen on the first appearance of cold weather.

How may the itching that attends the use of flannel be avoided? Why should especial care be paid to the protection of the feet? At what time should woolen clothing be put on?

The garments that are worn next the skin should be changed before they become saturated with secretions of the sebaceous glands. This can be accomplished by renewing them about twice a week, though the majority of people only change them once in the same period; but it is not sufficient. Clean clothing should always be well aired and dried, especially in the case of invalids. It is said that in Scotland, when a poor sick person is ordered a change of linen, it is the custom for a friend or relative to wear it for some days in order that it may be *well aired.* The effect of such a system is to render it utterly unfit for use, for it is permeated with the secretions of the skin of the first wearer; and, if he has been in the vicinity of, or is himself suffering from any contagious disease, it is very liable to be imparted to the sick man.

The shape or cut of the clothes has a certain amount of influence on the health of the wearer. In hot countries they should be ample and loose, so that the air they contain may be readily and frequently changed, and the emanations from the skin removed. Illustrations of this principle are afforded by the Persians, Arabians, and all nations that live in hot countries. In cold climates, on the contrary, the clothes are nearly always cut so as to fit the body closely, and retain the heat as much as possible.

As regards the use of ligatures around any part of the body, whether as stocks or tight neck-ties in men, or tight corsets and garters in women, we can only speak in condemnation; but so long as the fashions of America are originated by the Parisian lorettes, it is useless to attempt to resist any absurdity they may introduce. For the sake of those who think they must employ some such article of dress, we quote the recommendations of Dr. Goddard, in his essay on tight lacing. He says: "1st. Corsets should be made of smooth, soft, elastic materials; 2d. They should be accurately fitted, and modified to suit the peculiarities of figure of each wearer; 3d. No other stiffening should be used but that of quilting or padding: the bones, steel, etc., should be left to the deformed or diseased, for whom they were originally intended; 4th. Corsets should never be drawn so tight as to impede regular natural breathing, as, under all circumstances, the improvement of figure is insuf-

How often should the garments next the skin be changed? Why should clothing be aired before it is put on? What cut or shape should be given to the clothes? What difference in the method of cutting should be employed in different climates? Are corsets and such means of compression healthy? How should corsets be constructed and worn when they are used?

ficient to compensate for the air of awkward restraint caused by such lacing; 5th. They should never be worn, either loosely or tightly, during the hours appropriated to sleep, as, by impeding respiration, and accumulating the heat of the system improperly, they invariably injure; 6th. The corset for young persons should be of the simplest character, and worn in the lightest and easiest manner, allowing the lungs full play, and giving the form its full opportunity for expansion."

We have, in a previous lecture, drawn attention to the experiments of Franklin and Davy, which demonstrated that different-colored surfaces absorbed light with different degrees of rapidity; we now advance those of Dr. Stark on the power of cloth of different colors to absorb odors. The sense of smell shows that when portions of cloth of various shades are exposed to odorous gases or vapors, those which are darkest absorb the odoriferous particles with the greatest avidity. By employing camphor, Stark added ocular proof of the fact that the power of colored surfaces to absorb odorous particles depends on the depth of the color, those which are dark absorbing often more than twice as much as those which are of a light tint. To quote his own language: "If it be thus certain that odorous emanations have not only a particular affinity for different substances, but that the color of these substances materially affects their absorbing or radiating quality, the knowledge of these facts may afford useful hints for the preservation of the general health during the prevalence of contagious diseases. From their minute division and vast range of action, latent poisonous exhalations or effluvia, inappreciable by the balance, may no doubt exist to a dangerous extent without being evident to the sense of smell. But in most cases it will be found that, when contagious diseases prevail to such an extent, the emanations from the sick will, if attended to, give the surest indications of the contamination of the surrounding air. Besides, even if we allow that infectious emanations have no necessary connection with odors, the experiments will afford the strongest possible presumption that the emanations of an infectious nature, in common with odors, vapors, and emanations generally, are emitted on the one hand, and, on the other, received according to the same general laws. Next, therefore, to keeping the walls of hospitals, prisons, or apartments occupied by a number of individuals of a white color, I should suggest

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What were the experiments of Stark on the absorptive power of textures of different colors?

that the bedsteads, tables, seats, etc., should be painted white, and that the dresses of the nurses and hospital attendants should be of a light color. A regulation of this kind would possess the double advantage of enabling cleanliness to be enforced, at the same time that it presented the least absorbent surface to the emanations of disease.

"On the same principle, it would appear that physicians and others, by dressing in *black*, have unluckily chosen the color of all others the most absorbent of odorous and other exhalations, and of course the most dangerous to themselves and patients. Facts have been mentioned which make it next to certain that contagious diseases may be communicated to a third person through the medium of one who has been exposed to contagion, but himself not affected."

Though we may not accept all that Dr. Stark has stated, there can be but little doubt that dark-colored surfaces do absorb odorous and other emanations with greater avidity than those which are light, and his recommendations regarding the dresses of hospital nurses and patients are worthy of serious attention.

LECTURE LIII.

HYGIENE OF THE MUSCULAR, OSSEOUS, AND NERVOUS SYSTEMS.

Exercise necessary to the proper Maintenance of the Muscular and Nervous Systems.—Forms of Exercise.—Active and Passive Exercise.—Walking.—Leaping.—Running.—Dancing.—Fencing.—Boxing.—Wrestling.—Horseback Exercise.—Sailing.—Driving.—Passive Movements of different Limbs.—Amount of Exercise required by an Adult.—Incompatibility of Labor and Mental Activity.—Conditions requisite for the proper Development of Bone.

In order to preserve the muscular and osseous tissues in a perfect state of health, the first must be subjected to a certain amount of exercise, and the food must be adapted to the proper nutrition of the latter.

Exercise, to a suitable extent, is one of the essential conditions of health; it not only improves the tone of the muscular system, but it also imparts a stimulus to all the tissues and organs of the body. Its action on the digestive apparatus is universally known, and is appreciated to a greater or less extent by all.

What should be the color of the clothing of nurses? What are the conditions necessary to the proper maintenance of the muscular and osseous tissues?

Exercise may be either active or passive. In the first the muscles are thrown into action by the will of the individual; they consequently are nourished with greater perfection, increase in size, and become firm and hard, and are capable of enduring an immense amount of fatigue and labor. The fat that fills the interstices between the bands that compose the muscles, and that between the muscles themselves, is absorbed, and the outlines of these organs are sharply defined, and, at the same time, the limbs gain greater freedom of action. In passive exercise, on the contrary, the source of motion is extraneous to the body, and it is subjected to a series of forced movements; the organs of the system are stimulated by the succussion that attends these movements, and the muscles are thrown into activity that varies with the intensity of the original cause. In riding on horseback, for example, a very considerable amount of muscular exertion is necessary in order to retain one's seat when the motion is rapid.

Of all the forms of active exercise, that which is attendant on travel is the most beneficial, on account of the constantly recurring changes of air, and the continual stimulation of the senses by the numerous novelties that are presented in rapid succession. With the improvement in the tone of the nervous system that follows on this grateful stimulation of the senses, there is increased appetite; the traveler eats heartily and sleeps soundly; digestion and absorption are benefited, and the tone of all the tissues and organs elevated.

The gentlest form of active exercise is walking on a level surface; the muscles of the extremities, trunk, abdomen, and neck are thrown into a moderate action, which does not easily produce fatigue. In ascending and descending a hill-side the motion is more violent and the succussion is greater, consequently fatigue is more rapidly induced.

Rowing is an excellent form of exercise, which may be adapted to all periods of life, from the mere child to the old man. It is of great value to young men, since it tends to develop the muscles of the chest; and when the exertion is great, as in racing, nearly all the muscles of the body and lower extremities are also thrown into violent action.

The exercise of leaping or jumping jars the body violently; it is only suitable to the period of youth, when the cartilages

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What are the forms of exercise? How does active exercise act? How does passive exercise act? What form of exercise is most beneficial? What is the gentlest form of exercise? How does rowing act? How does leaping act on the organs?

are soft, and can, by their elasticity, moderate the violence of the succussion. In adults and in old people, in whom the cartilages have become indurated, and have lost, to a certain extent, their elasticity, it is highly improper, and is frequently followed by serious consequences.

In running there is a succession of leaps, which quickly produces fatigue, and excites the organs of circulation and respiration violently; it is also only suited to the earlier periods of life

Dancing is a compound of stepping and leaping, frequently attended by a movement of gyration, and diversified with periods of rest; the mind is at the same time stimulated by the music, and the brilliant costumes and merry faces aid in making it one of the best forms of exercise when not carried to excess. Where there is any organic disease of the heart or lungs it should be avoided, and during the periods of gestation and menstruation it is apt to produce serious consequences.

Fencing rapidly develops all the muscles of the upper extremities, and of the trunk and lower extremities. It also necessitates great activity of the mind and senses, in order to guard against the attack of the opponent. Boxing and wrestling are very similar in character to fencing; they are only adapted to the periods of youth and manhood.

Of the forms of passive exercise we have already stated that horseback riding is the best; next to this we may place riding in a carriage, which may be varied in the intensity of its effect by the nature of the vehicle.

Sailing is another form of passive exercise, the effect of which depends in a great measure on the change of air and continued succession of novelties, but which also brings to some the long train of uncomfortable sensations included under the name of sea-sickness, the explanation of which is still involved in mystery; but, in spite of this drawback, it is one of the best forms of exercise for the majority of invalids, and is often one of the best remedial agents that can be employed during convalescence.

When the system is debilitated by disease it is often incapable of any of the modes of exercise mentioned above; under these circumstances, gentler forms of movement are often productive of excellent results. If the sick man is too weak to

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How does running act? At what periods of life should leaping and running be indulged in? Under what circumstances should dancing be avoided? How does fencing act—boxing—wrestling? What is the best form of passive exercise? How does sailing act?

ride in a carriage, the use of passive motion, in which the limbs are moved by another person, and the skin gently rubbed, will be found to aid in improving both the appetite and the action of the different organs.

The amount of exercise required by different persons varies greatly, but a walk of four or six miles a day seems to agree with the constitutions of the majority of men; they eat and sleep better, and all the functions of their systems are performed with greater satisfaction when a certain amount of exercise is taken daily. But no definite rule can be established; every individual must experiment for himself, and determine the amount of physical exertion necessary for the well-being of his own system.

Exercise is, of course, a subject of no interest whatever to a laboring man; but to those who follow sedentary pursuits it is of vital importance, and especially to the student, who is only too apt, when carried away by the desire to attain mental and intellectual improvement, to forget the absolute necessity of paying some attention to the wants of the body. It is to this class that we would earnestly appeal, and urge the necessity of spending one or two hours a day in outdoor exercise, that their bodies may be fitted to bear the strain which the nervous system is compelled to endure.

It is an old saying that a sound mind requires a sound body; yet, though parents are continually repeating it, and applying it to the children of their neighbors, they rarely apply it to their own, but endeavor to drive them through school into college or business long before they are fitted physically for the mental effort to which they are subjected. The evil consequences of such a forcing system are to be seen in every direction. How many unfortunate children can every teacher point out within the limit of his own experience who have been utterly disheartened and discouraged, and have finally formed an unconquerable distaste for every variety of mental pursuit, because they have been forced to undertake tasks which they were too young and feeble to accomplish.

Though a certain amount of exercise is necessary to the well-being of the system, and enables it to undertake mental labor with greater satisfaction and better results, it may be readily carried to excess, and produce the opposite effect; intense, long-continued muscular labor is incompatible with intellectual ad-

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Under what circumstances should driving and the passive motion of separate limbs be employed? What is the average amount of exercise required by a healthy adult?

vancement. The laborer is too weary to study; all his nervous force is expended on his muscles, and there is nothing left to stimulate the intellect.

The osseous system requires a liberal supply of phosphates of lime for its proper development and support; these must necessarily be introduced in the food; but, as we advance in civilization and in the social scale, it seems as if we endeavored to render our bodies more and more liable to disease, by changing the character of the diet, and rendering it less able to supply the wants of the system.

The greatest demand for phosphates exists during infancy and childhood; they should therefore be supplied most freely at this period. The mother or nurse should use bread made from flour that retains a part of the covering of the grain; and when the child is weaned, coarse brown bread is a far better article of diet than the fine white bread, which contains but a very small proportion of phosphates.

LECTURE LIV.

PROPHYLACTICS.

History of Jenner's Discovery of Vaccination.—Quarantine.—Fomites.—Conditions that favor the spread of Cholera and the Fevers.—Purification of Streets and Public Places.—Purification of Private and Tenement Houses.—Personal Prophylaxis.—Insanity.—Cancer.—Phthisis.—Effects of Intermarriages.—Conclusion.

The last division of the subject of hygiene is the use of prophylactics, by which we mean the methods or drugs employed to enable the system to avoid disease. The best example of such methods is vaccination, for which we are indebted to Jenner, who noticed that the girls employed in milking on dairy-farms contracted sores on their hands, derived from small ulcers on the teats of the cows, and were not attacked by small-pox. Suspecting that the vaccinia of the cow-teat was the agent that protected the milkmaids from the small-pox, he submitted his theory to the test of experiment, and found that it was correct.

Since the introduction of Jenner's system of vaccination, the

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Are labor and mental activity compatible? What is the essential condition for the proper nutrition of the osseous system? At what period of life is the greatest supply of phosphates required? What variety of bread furnishes the largest amount of phosphates? What are prophylactics? What is the history of vaccination?

small-pox, which was before his time a terrible plague, carrying off whole communities in a season, has now become so modified that it is comparatively rare, and scarcely ever appears among the nations that maintain a strict system of vaccination.

As an example of the employment of drugs as prophylactics, we may cite the use of quinine as a protection against the malarial poisons of our Southern States. During the past war it was administered as a regular ration to the troops stationed in districts in which the various types of intermittent and remittent fevers prevailed, and was found to reduce greatly the proportion of such fevers.

One of the most important prophylactic measures is the quarantine. It is established by all civilized communities for their protection against various plagues, and is founded upon the fact that such diseases are conveyed either by persons suffering from them, or by contact with infected clothing, bedding, or other substances that have been in contact with the body of a person afflicted with a contagious disease. Infected articles are called fomites, which term embraces every variety of object, from the smallest piece of clothing to the largest ships and hospitals.

When the fomites are small, consisting of clothing, bedding, and such articles, the quarantine laws generally demand that they shall be burned, while vessels and buildings are subjected to a thorough system of purification by fumigation, or the use of solutions of chlorine. Whatever opinions may be held regarding the conveyance of contagious diseases by fomites, the experience of all maritime nations has shown that the establishment of a strict quarantine is the only protection that human ingenuity has devised against their advance; and though it may not succeed in arresting them, it is more or less effective in retarding them, and enabling families and communities to perfect their arrangements for avoiding their influence.

The fearful epidemic scourges which from time to time sweep over the whole civilized world may be greatly modified in their character and reduced in intensity by the adoption of proper hygienic means. We have already seen how the discovery of Jenner has lowered the mortality of small-pox; and though we do not possess any such specific protection as vaccination in the case of typhoid or typhus fever, yellow fever,

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What effect has vaccination had on the spread of small-pox? Give an example of the use of drugs as prophylactics. What is the object of the quarantine? What are fomites?

and cholera, we can, by paying ordinary attention to the hygienic condition of our streets, houses, persons, and food, reduce greatly the chances of being attacked by these diseases.

The spread of the fevers and cholera is governed by three conditions: the first is contact with effluvia emanating from the persons of individuals or fomites; 2d, a favorable state of the atmosphere; and, 3d, a favorable condition of the body of the individual exposed to the action of poisonous emanations.

Whatever opinions may be held regarding the contagious character of certain diseases, even the most ardent supporters of the non-contagious theory do not care to expose themselves unnecessarily to the chances of contact either with the persons or clothing of those who are diseased. We all, therefore, rely to a certain extent on the quarantine to protect us as far as possible from the introduction of fomites which may become foci or points of origin of the disease in our great commercial cities.

When the disease has appeared, every one is liable at any moment to come in contact with the poison either in the streets, stores, or public conveyances; we should therefore insist upon the careful cleaning of our streets, and the removal of all offensive matter which may by its decomposition render the atmosphere impure, and consequently more favorable to the conveyance and extension of the disease by reducing the tone and resisting power of our bodies.

The cleansing and use of such disinfecting agents as the chloride of lime in the streets is very important, but it is equally important that the air of our houses should also be purified. It is said that in many of the houses in New York the servants first light the fires and pump the water out of the cellars: though this may be an exaggeration, we all know that a damp cellar is the rule and a dry one the exception. In Lecture L. we have seen that a damp condition of the atmosphere is peculiarly favorable to the conveyance of all volatile exhalations, and also reduces the tone of the system; it is therefore very important that the cellar of every house, whether private or tenement, should be properly cleansed, dried, and ventilated during the years when the epidemic diseases are raging, if at no other time.

In the winter season the furnace will generally produce a sufficient ventilation of the cellar, and prevent the foul air entering the house; but in the spring and summer, when cholera commences to rage with the greatest violence, the furnace is

then extinguished, and there is no ventilation of the cellar. At this time the danger which impends may to a great extent be avoided by placing a small stove in it, in which a fire should be kept burning continually; by opening a communication with one of the chimney-flues and the top of the cellar the ventilation will be most complete, for the air which passes down the gratings will escape partly by such an opening and partly through the stove near the floor, securing a change of the atmosphere in all parts of the space. If the cellar is long it would be well to place the stove at one extremity, and pass the pipe through the whole length of the apartment, to secure warmth and ventilation in all its divisions.

Having provided suitable ventilation, the sewerage should be put in thorough repair, for in many houses the waste-pipes leak, and are continually delivering fluids laden with organic matter into the cellar, where they assist in producing noxious vapors, which are also continually arising from soil that has been filled in in leveling the streets and lots, and which is composed often of the worst kinds of rubbish. In order to destroy as far as possible the vapors which originate from these or other causes, it is best to scatter some disinfectant, as the chloride of lime, over the floor or pavement, to prevent their introduction into the atmosphere.

Next in importance to the purification of the air of our streets and houses is a proper attention to the condition of the skin and the character of the food. Every one should wash the whole surface of the body every day, or at least twice a week. In these general applications soap should not be used more than once a week, for it is not desired to remove the oily secretions too often, but merely wash off the salts that are excreted so freely in the form of perspiration during the warm weather. It is not necessary that the body should be immersed in water; a sponge-bath, or wet towel and a basin of tepid water, will answer the purpose perfectly, since the object is to keep the surface of the skin clean, and free from all secretions soluble in water.

As regards the clothing, many recommend that a flannel bandage should be worn over the abdomen; but it is better to extend the application all over the surface of the body, and wear a light flannel or merino shirt and drawers all the summer: these should be removed at night, and hung up to be dried and aired. When the weather is warm, or perspiration has been very free on account of violent exercise or other cause,

the flannel under-clothing should be changed two or three times a week; it would be better to change it every day, when circumstances permit.

Cholera and typhoid fever are both attended by great disturbance of the digestive apparatus, a severe diarrhœa being generally one of the first symptoms that attracts the notice of the sufferer; and there is no doubt that the use of some indigestible article of food, or exposure of the skin to draughts without suitable protection, is frequently the exciting cause of an attack of cholera or fever, which might otherwise have been avoided. The effect of sudden change in the temperature or dew point of the air we may avoid by the use of flannel, but the avoidance of indigestible articles is only to be accomplished by a careful personal observation of each individual regarding the articles of food which agree or disagree with his own digestive system, and in which he may be guided by an examination of the lectures on food and the methods of cooking.

In selecting the articles to be employed as food during the prevalence of cholera, we may, as a general rule, assert that all vegetables sold in the great cities are unsafe; they are rarely fresh, and the best have been generally plucked or gathered two or three days before they reach the table. The greatest care should therefore be taken in the purchase and selection of fruits and vegetables, and it would perhaps be best to avoid their use altogether, and adopt a bread and meat diet, to which some alcoholic stimulant, tea or coffee, is added. Of the alcoholic stimulants, whisky and brandy are the best; the different varieties of beer and ale are all laxative in their nature, and are very apt to undergo fermentation in the stomachs of those unaccustomed to them. The use of Cayenne pepper is highly recommended, and, if employed in small quantities, can certainly do no harm, and may be productive of great good; it should be employed as a condiment with the meats.

The last and most important of all the hygienic means is a perfect freedom of the mind from all depressing influences, and especially from fear. By adopting and following the simple rules laid down in the preceding paragraphs, we place our systems in the most favorable condition for resisting the attack of epidemic diseases, and avoid the causes which tend to provoke or excite their onslaught. We may therefore rest assured that our chances of escape are great; and when we reflect how small a percentage of the population falls under the epidemic, it is not in reality as fearful as it at first appears, and all may

rationally feel that a reasonable attention to the laws of hygiene will insure comparative immunity from such diseases.

In the division or class of prophylactics we may include the study of the origin of insanity, and the methods by which it may be avoided. One of the most influential causes of the production of insanity is the presence of the disease in one or both of the parents. Whenever it is known to exist, the unfortunate should not marry; for, though the disease may not appear in the child of such a person, it is liable to break out at any time, even in the third or fourth generation, blighting the life not only of the sufferer, but of all with whom he is related, since they are forced to the sudden realization of the awful fact that they too may at any moment be struck down, and forced to spend the remainder of their lives in an asylum. Society therefore demands, as an act of humanity, and a protection of its own integrity, that an insane person should not marry, so that with his death the disease may die also.

In some instances insanity appears or is directly produced by some intense mental excitement, as that attending great grief or joy; but it is generally found that even in these cases there is a lurking taint in the family, which has been called forth by the sudden excitement. The only cases in which insanity arises without the existence of some previous taint is either after violent inflammation of the brain, or when the parents have been closely related. Both the civil and religious law have exerted their power to prevent the latter custom; and society has so recognized intermarriage of the members of the same family as the chief origin of idiotcy and insanity, that when such marriages occur they are universally condemned, and the products regarded with suspicion, as being candidates at any moment for the asylum.

The effects of any great popular or national excitement may always be traced in the asylums of a nation by the increase in the proportion of insane persons, all great wars, religious discussions or revivals invariably producing a disastrous effect on those who are disposed, by hereditary taint, to this fearful disease. Communities in which there is great activity of mind present conditions favorable to the development of the disease; we consequently find that, on examining the census statistics, it is comparatively rare among the Southern slaves, while it is common in New England.

Though we can not control the causes which are the immediate excitants of insanity, we can, to a certain extent, prevent

its increase by a proper attention to the prevention of intermarriages between those who are closely related, or who already possess traces of the disease.

Phthisis and cancer are also peculiarly liable to transmission from one generation to another. They may, of course, arise spontaneously, but in the great majority of cases they are hereditary; and so clearly is this fact recognized by physicians, that almost the first question put to a person suffering from either is, "Of what disease did your parents die?" In these cases, as in that of insanity, society again demands that it shall be protected, and frowns upon all marriages in which such a taint is known to exist.

Though the all-important subject of Hygiene deserves a far more extended consideration than it has received in this work, and could of itself fill many volumes, we have given it all the space that circumstances allowed, and have presented many facts of general interest and importance. If a close examination of these should lead to the adoption of a course of living which may render the life of even a single individual more endurable or enjoyable, we shall feel that our task has accomplished its end.

INDEX.

THE END.

Daily secretion of Bile = 3-4 Oz.
" " " Pancreas = 30

The ferment of Bile is called = Cholesterine
" " " Pancreas " " = Pancreatine
" " " Stomach " " = Pepsin -